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THEORY OF ARCHES.

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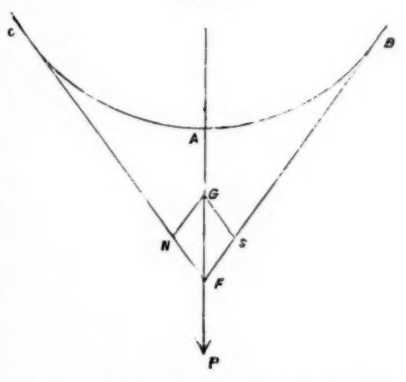
The following is an amplification and explanation of Professor Rankine's chapters on this subject.

Perhaps the clearest way of developing the "Theory of Arches" is to begin with the consideration of the forces which act upon a suspended chain or cord. The force in the chain or cord is just the opposite of that upon an arch—that is—it is *tension* instead of *compression*, but the relations between the "external" and "internal" forces, or what is the same, between the loads and the resistances they produce, are strictly analogous.

Let C A B (Fig. 1) be a cord suspended at C and B and loaded in any manner over its whole length. Consider the forces acting on this cord. Suppose it attached to a hook at B and to another at C. A cord without stiffness cannot exert a pull except in the direction of its length: therefore the "pulls" in the rope at C and B, and exerted at these points on the suspending hooks, must be in the direction of the tangents at those points. The load is supposed to be distributed over the cord, but we may find its resultant. Let P be this resultant and P F its direction. The *three* forces, viz.: the pulls at C and B, and the resultant of the load, P, are all in the same vertical plane; they are the only forces acting on the cord; and as they are in equilibrium, the *directions of these three forces must meet in one point*, and the forces themselves *must be proportional to the three sides of a triangle drawn parallel to their directions.*

G N F (Fig. 1) is such a triangle. The known directions of the pulls at B and C, and of P, give us the angles in this triangle; and if we know also the magnitude

Fig. 1.



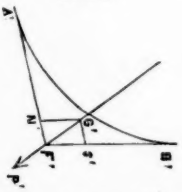
of the load P, represented by the line G F, we can determine that of the pulls at B and C. For

(Pull at B = G N) : G F : : sin G F N : sin G N F.
(Pull at C = N F) . G F : : sin N G F : sin G N F.

The analysis we have made for the whole cord may be applied to any part of it. Thus, if we consider any arc B′ A′ (Fig. 2) of the cord, and the load on that arc, we have three forces in the same plane in equilibrium. For at A′ and B′ the other parts of the cord may be replaced by two hooks,

and the pulls on these hooks, exerted by the cord at A′ and B′, will be, as before, in the direction of the tangents at those points. The resultant P′ of the load on A′ B′ must pass through the point of intersection of the tangents, and if the direction of that resultant be as indicated in the figure, then G′ N′ F′ will be the triangle of forces.

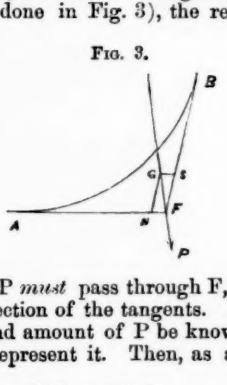
FIG. 2.



The principles above explained enable us to calculate the "pulls" at all points of a loaded chain or cord, and consequently to fix *its size and strength to bear* a given load; or to determine the *amount, distribution, and direction of the load* necessary to produce assumed "pulls" in a cord of a given shape.

Thus suppose in the half of the loaded cord of (Fig. 1) we draw the tangents at A and B (as is done in Fig. 3), the resultant of

FIG. 3.



the load P *must* pass through F, the point of intersection of the tangents. If the direction and amount of P be known, lay off F G to represent it. Then, as above explained,

N F = pull at A

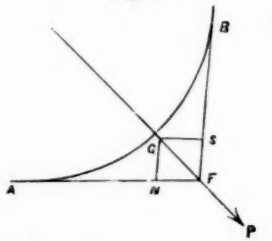
and

N G = pull at B.

Suppose, on the other hand, we assume the pulls at A and B to be equal, we lay off on the two tangents (Fig. 4), equal lengths, F S and F N, to represent these equal pulls, and upon them construct a parallelogram. Then F G gives the magnitude and direction of the resultant of the load that must be put on the cord to produce the given pulls.

A cord is in *equilibrium* when it is balanced under the load applied. Change the distribution of the load and the cord

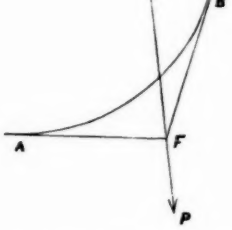
Fig. 4.



at once charges shape and assumes the form necessary to equilibrium under the new load.

Thus, if P (Fig. 5) equals the direction of the resultant of the new load on the cord from the horizontal point A to the point of support B, draw the tangent A F, until it meets the direction of the load P, at F; then draw F B. The cord A B will have so changed its form that F B (Fig. 5) will now be the direction of the tangent at B.

FIG. 5.



FORMS OF CORDS UNDER VARIOUS LOADS.

Let us now investigate the various curves which a cord will assume under different distributions of the load.

Case I. Suppose the load to be altogether *vertical*, and to be distributed *uniformly* along the *horizontal*.

Let *equal* weights be hung, for instance, along a cord C B (Fig. 6) so that the *horizontal* distance between the threads by which the weights are suspended shall be everywhere equal. Or, draw little elementary triangles along the curve, so that the *bases* of all these little triangles shall be equal, and let the threads holding the weights cut the middle of these bases.

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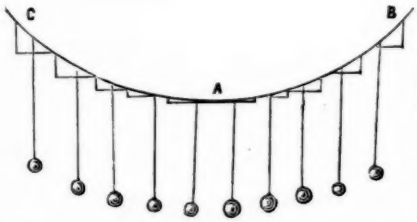
Then each weight may be considered as the resultant of the load on the element of the curve which constitutes the hypothenuse of the little triangle to which it is attached. Such a load is *vertical* and is *uniformly distributed along the horizontal.*

FIG. 6.

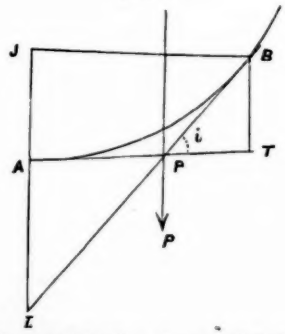


To determine the curve of the cord. Obtain the resultant of the load between the horizontal point A and the point B (Fig. 7). This resultant, as the little forces are all parallel, is equal to the sum of them, and it is vertical in direction. It will also evidently bisect A T. Draw it, and from its point of intersection with A T, draw the line F B, which, as has been shown, must be tangent at B. Prolong B F to I, then the subtangent I J is seen to be bisected at the vertex A of the curve. Hence the curve C B is a *parabola.*

The triangle B F T has its sides parallel to the forces acting on the half cord A B; so that if B T be taken to represent P,

B F = pull at B
F T = pull at A.

FIG. 7.



Let T = equal tension at any point along the cord.
H = value of T at the horizontal point A, or the "horizontal pull" on the cord.
i = inclination of the tangent at any point to the horizontal.

Then as the arc A B (Fig. 7) may stand for any part of the curve counting from the horizontal point A towards one of the points of suspension, we have the following general equations from the triangle B F T:

$$T^2 = P^2 + H^2 \qquad (1.)$$

$$\text{Tan } i = \frac{P}{4} = \frac{px}{H} = \frac{dy}{dx} \qquad (2.)$$

(p being = the load per unit of horizontal distance, A the origin of co-ordinates, A T = axis of X and A J = axis of y).

From equations (1) and (2) we can solve three problems.

1. Given the *curve*, and the *load*, to find T and H.

2. Given the *curve*, and T and H, to find P.

3. Given the *load*, and T and H, to find the curve.

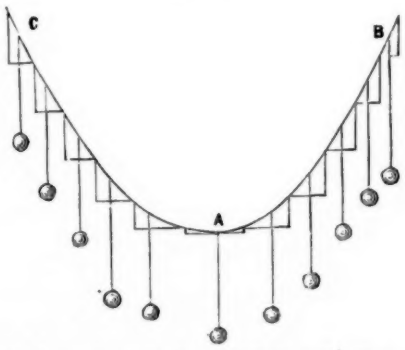
For a full discussion of this case, see Rankine's "Civil Engineering."

Such a distribution of the load as we have discussed in the above case, is approximated to in suspension bridges, and sometimes in wood, iron, or steel arches, but not usually in stone or brick ones.

Case II. Let the load still be *vertical*, but distributed *uniformly along the curve.*

That is, divide the arc C A B (Fig. 8)

FIG. 8.

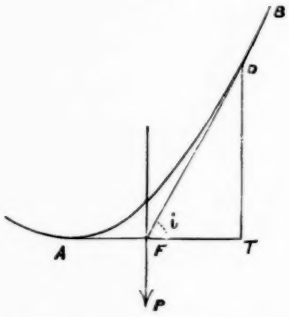


into elements each of a unit in length; then the load on these elements is constant throughout. It is easily seen that such a load is not, as in the last case, uniform along the *horizontal*, for the *basis* of the little triangles of which the *hypothenuses* are now equal, diminish in extent as we go from A towards B or C. A chain of uni-

form material and cross-section and acted on by nothing but its own weight, is in the condition described, and, as is well known, the curve assumed by it is the "common catenary."

Let p = weight of a unit's length of the cord, then if $p\,m$ = horizontal pull on the cord at A = H, m is called the *modulus* of the *catenary*, and represents the length of cord of the same kind as C B, the weight of which would equal the pull at A. The weight on A B = P = $p\,s$ when s = length of cord A B.

FIG. 9.



The triangle of forces for any arc A D (Fig. 9) can be found as before, by drawing the tangents at A and D, and the line representing the force P vertically through their intersections. The triangle D F T will represent the forces; D T being P = $p\,s$, and F T = H = $p\,m$, and D F = T = tension at D. Then

$$T^2 = H^2 + P^2 = p^2 m^2 + p^2 s^2 = p^2 (s^2 + m^2) \quad (3.)$$

$$\text{Tan } i = \frac{D\,T}{F\,T} = \frac{p\,s}{p\,m} = \frac{s}{m} = \frac{d\,y}{d\,x} \quad (4.)$$

From the differential equation

$$\frac{d\,y}{d\,x} = \frac{s}{m}$$

we obtain the linear equation of the curve. In doing so it is most convenient to take the origin at a point O, whose distance below the vertex A is = m. The line Q O X (Fig. 10) is called the *directrix* of the catenary.

The equations of the catenary are

$$s = \frac{m}{2}\left\{ E^{\frac{x}{m}} - E^{-\frac{x}{m}} \right\} = \sqrt{y^2 + m^2} = \text{length of arc.} \quad (5.)$$

$$y = \frac{m}{2}\left\{ E^{\frac{x}{m}} + E^{-\frac{x}{m}} \right\} = \sqrt{s^2 + m^2} \quad (6.)$$

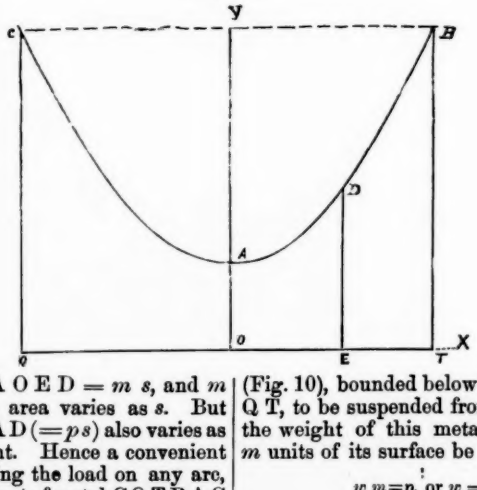
$$x = m.\ \text{hy. log.} \left\{ \frac{1}{\frac{y}{m} + \sqrt{\frac{y^2}{m^2} - 1}} \right\} \quad (7.)$$

$$\text{Area A O E D} = \int y\,dx = m\,s \quad (8.)$$

$$\text{Tan } i = \frac{s}{m} = \tfrac{1}{2}\left\{ E^{\frac{x}{m}} - E^{-\frac{x}{m}} \right\} \quad (9.)$$

$$\text{Radius of curv.} = C = \frac{y^2}{m^2} = \frac{m^2 + s^2}{m} \quad (10.)$$

FIG. 10.



Since the area A O E D = $m\,s$, and m = a constant, the area varies as s. But the load on the arc A D (= $p\,s$) also varies as s, since p is constant. Hence a convenient mode of representing the load on any arc, A D. Suppose a sheet of metal C Q T B A C (Fig. 10), bounded below by the "directrix," Q T, to be suspended from the curve. Let the weight of this metal corresponding to m units of its surface be = p. That is, let

$$w\,m = p, \text{ or } w = \frac{p}{m}.$$

The weight of a strip a *unit in breadth* extending from A to O is then $= p =$ the weight of a unit's length of the cord. Then the part of the sheet A O D E whose weight $= w\,m\,s = p\,s$, represents the weight P on the arc A D. So A O B T represents the weight on A B, and C Q T B the whole weight on C A B. In the horizontal pull at A we have

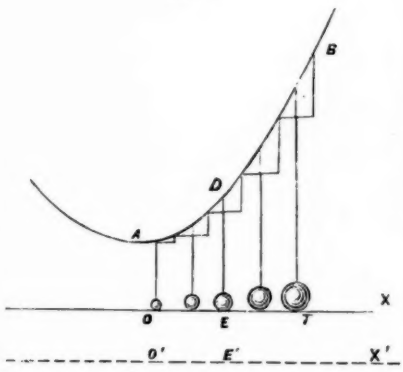
$$H = p\,m = w\,m^2 \qquad (11.)$$

and at any point D

$$T = \sqrt{\tfrac{1}{4}^2 + P^2} = p\sqrt{s^2 + m^2} = p\,y = w\,m\,y. \qquad (12.)$$

The property above explained may be illustrated in another way.

FIG. 11.



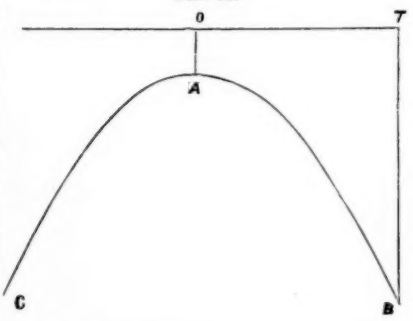
Constant on A B (Fig. 11) a series of little triangles with all their *bases* equal. Let the weights of the little arcs constituting the hypothenuses of these triangles be represented by balls suspended by threads from the middle of each little arc. Take the length of the thread corresponding to the ball at A as $= m$; make the lengths of all the threads proportional to the weights of the balls hung to them; then the lower ends of these lines will all be on the directrix O X. That is, the *intensity* of the load on a catenary along the horizontal line (weight on a unit of horizontal distance) varies as the *ordinates* of the catenary, when those ordinates are measured from the directrix.

It makes no difference in the form of the curve A B (Fig. 11), to increase or diminish the weights provided the *proportion* among them is preserved. Thus we may assume the cord and the sheet C Q T B (Fig 10), to be of a different material in which a unit's length of the cord shall in weight $= p'$, and the weight of the sheet per unit of surface shall $= w'$, and A B will be unchanged. Note, however, that we cannot change the depth A O of the sheet (Fig. 10), nor the length of the lines (Fig. 11), without changing the curve, for if the lines ended in O' X' for instance, instead of O X, then $\frac{A\,O}{D\,E}$ would *not* be equal to $\frac{A\,O'}{D\,E'}$.

Hence, the *modulus* ($m = A\,O$) fixes the catenary, or if we assume the catenary, this determines the modulus. Thus if we assume three points, B, A, C (Fig. 10), on the catenary the distance A O is thereby determined; and if we assume A O and the point A we cannot generally assume B and C.

This often interferes with the use of the "common catenary" in the building of arches (in which case the curve is inverted, the metal sheet A O T D is replaced by a wall of uniform material, and the tension on its cord, C B (Fig. 10), is replaced by a thrust along C A B (Fig. 12). For we are often compelled to make the curve pass through three points, while yet the value of A O is fixed.

FIG. 12.

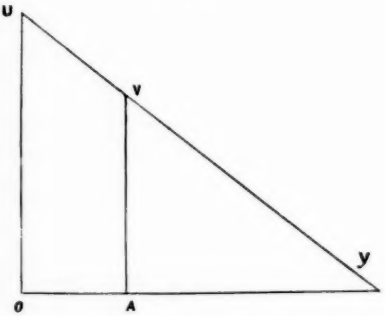


But this difficulty may be obviated by the use of the *transformed catenary*, which we will now discuss.

Case III. By the principle of *Parallel Projections*, if any cord or arched rib is balanced under a system of forces which are represented in the figure by lines, and a *parallel projection* be made of the curve of the cord or rib and of the lines representing the forces, then the new curve will represent a cord or rib that will be balanced under the forces represented by the new lines.

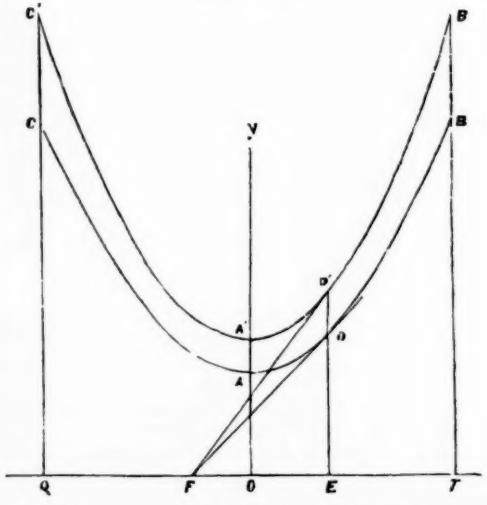
Imagine a cylindrical surface constructed upon C Q T B A C (Fig. 10) as a base. To simplify matters, suppose the elements of the cylinder to be perpendicular to the plane of the base. Cut this cylinder by a plane inclined to the base, and we shall get a "Transformed Catenary," and the shape of the sheet of metal under which it will be balanced; for the new curve and surface cut out by the inclined plane are the *parallel projections* of the curve C A B and the surface C Q T B A C (Fig. 10). Let this inclined plane be so placed that it shall intersect the plane of the base in the straight line C B (Fig. 10) or in one parallel to it. Then all horizontal lines (or those parallel to C B or Q T) will be unchanged in length in the parallel projection, while all vertical lines (those parallel to A O, etc.) will be lengthened in a constant ratio whose magnitude will depend upon the inclination of the cutting plane. Make a vertical section of the cylinder on the line OY. Then if the cutting plane passes though C B we get the triangle O U Y (Fig. 13*a*)

FIG 13 (*a*).



the *common catenary*, and all lines parallel to U V are evidently increased over the corresponding ones of which they are the

FIG. 13 (*b*).



parallel projections, in the same ratio that U V exceeds O A. Laid down in the same plane the two curves are C A B and C′ A′ B′ (Fig. 13 *b*).

It is easy to pass from a given catenary to a transformed catenary whose ordinates shall be *shorter* instead of *longer* than those of the given curve, by erecting an oblique cylinder on the given catenary and surface C Q T B, and cutting it by a plane less oblique than the base. So too, the horizontal dimensions can be changed instead of the vertical, by making the cutting plane meet the base in a line parallel to O Y, instead of in one parallel to Q T.

The equations of the curve C′ A′ B′ (Fig.

13 *b*,) are thus obtained. The *abscissas* are the same as those in C A B, but the ordinates are changed, so that (if y' = general ordinate of C′ A′ B′ and y_o' = A′ O, the ordinate at the vertex A′).

$$y' : y \; : : \; A'O : AO \; : : \; y_o' : m.$$

$$\therefore y' = \frac{y_o}{m} \cdot y \text{ or } y = y' \frac{m}{y_o}$$

In the equations of the common catenary substitute y' for y and we have the equations of C′ A′ B′.

From equation (6)

$$\frac{m}{y_o} \cdot y' = \frac{m}{2} \left\{ E^{\frac{x}{m}} + E^{-\frac{x}{m}} \right\}$$

$$\therefore y' = \frac{y_o}{2} \left\{ E^{\frac{x}{m}} + E^{-\frac{x}{m}} \right\} \qquad (13.)$$

So equation (7) becomes

$$x = m \text{ hy. log.} \left\{ \frac{1}{\frac{y'}{y_o} + \sqrt{\frac{y'^2}{y_o^2} - 1}} \right\} \qquad (14.)$$

So equation (8) or are a A′ O E D′.

$$= \int y' \, dx = \frac{m \, y_o}{2} \left\{ E^{\frac{x}{m}} - E^{-\frac{x}{m}} \right\} \qquad (15.)$$

etc., etc., etc.

The "triangle of forces" F E D (Fig. 13), for any arc A D of the catenary, becomes F E D′ for the arc A′ D′ of the transformed catenary—that is—since the horizontal lines —forces are unchanged.

$$\text{Tension at vertex A}' = H' = H = w \, m^2 \qquad (16.)$$

Load on A′ D′ is increased in ratio of A′ O to A O or of D′ E to D E.

$$\therefore P' = P \cdot \frac{D'E}{DE} = P \cdot \frac{y_o}{m} \qquad (17.)$$

(D′ E represents this load.)

Then tension at D′ is

$$T' = \sqrt{P'^2 + H^2} \qquad (18.)$$

and

$$\text{Tan } i = \frac{d\,y'}{d\,x} = \frac{y_o}{2\,m} \left\{ E^{\frac{x}{m}} - E^{-\frac{x}{m}} \right\} \qquad (19.)$$

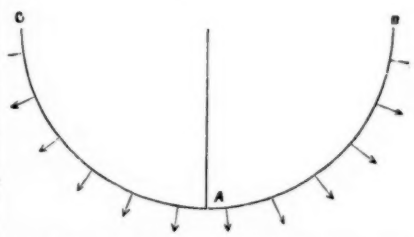
In this curve we can assume the directrix Q T, the distance A′ O (= y_o) and also the points B′ and C′. These quantities assumed, we determine m (the modulus of the corresponding common catenary) from equation (14), and then by equation (13) find points of the transformed catenary.

From equations (18) and (19) we can solve three problems similar to those given under the head of Case I.

Case IV. So far we have discussed the forms of cords under loads *parallel* and altogether *vertical*. Let us take up the cases of loads varying in direction.

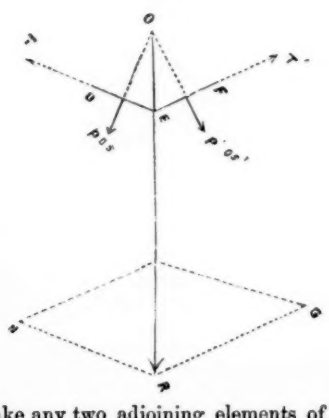
Suppose (as Case IV.) that the load is *uniform* and *normal* at *every point* to the cord. Such a load is represented in (Fig. 14), the load on each element $d\,s$ of the curve being constant and perpendicular to it.

FIG. 14.



It is first to be noted that the pull or tension on a cord under *any* load which is *everywhere normal* to it, must be *constant*. That is, the pull along the cord at A and B, and at all other points, is one and the same. That the tension at B in the cases previously discussed is greater than at A, is due to the fact that the elements of the load between A and B have in those cases *tangential* components, which go to change the value of the pull along the cord. But in the present case, the load being *everywhere* normal, there are no such tangential components, and therefore the "pull" does not change.

FIG. 15.



Take any two adjoining elements of the cord $d\,s$ (= D E, Fig. 15) and $d\,s'$ (= E F, Fig. 15), each of such length as to corres-

pond to equal elements of the load. The little loads on these lines we will represent by $p\ d\ s$, and $p'\ d\ s'$. Note, that unless the load be uniform all around the cord, $d\ s$ will not be equal to $d\ s'$. The equal loads $p\ d\ s$ and $p'\ d\ s'$ being normal respectively to D E and E F, their resultant which lies in the direction O R (Fig. 15) bisects the angle between $p\ d\ s$ and $p'\ d\ s'$, and also the angle D E F between $d\ s$ and $d\ s'$, which last is the angle between the direction of the pulls T and T' on the cord at D F. Hence the parallelogram of forces (as shown at R) will be a rhombus, or

$$N\,R = T = R\,G = T'$$

(To be continued.)

THE DRAINAGE OF SMALL TOWNS.*

From "The Building News."

In his introductory remarks, Mr. Whitaker said he attributed in a great measure the slow progress made in the sanitary improvement of our towns, and the fearful delays that continually occurred, to the disgraceful apathy, combined with etiquette and routine that existed at headquarters, as well as to the ignorance, obstinacy, and penuriousness of local boards and sewer authorities. The Minister or the Member of Parliament brought forward a bill that was full of good intentions, but it dared not attack anything in the shape of a "vested interest" or its fate was sealed. Witness the Public Health Act of last year. Its most potent clauses had all to be thrown overboard in order that the bill might pass. In individual cases, the endless correspondence, forms and stipulations, tended so much to delay, that what would be done by a private firm in a few days, took months of official time to accomplish. Mr. Whitaker instanced the case of a town which was visited twice by a medical and once by an engineering inspector of the Government, over three years ago, and pronounced to be in a disgustingly foul and unhealthy state. A system of drainage and water supply was ordered to be immediately carried out; but by a cunning method of working the cumbrous machinery, both central and local, which was provided, the Obstructives managed to have their way and nothing had yet been done. Other such cases might be instanced, until it would almost seem that Acts of Parliament hindered rather than promoted sanitary work. The delays and obstructions which arose were too readily taken advantage of by the ignorant and prejudiced vestrymen. Mr. Whitaker did not deprecate the principle of a central authority, for he believed that it was only by means of the compulsory powers of a Government Board that the improvement of the sanitary condition of the country would ever be effected. It was all very well to advocate local self-government, and rail at centralization; but until sanitary authorities were educated sufficiently to appreciate the value of sanitary measures, they must be led or driven by some power wiser than themselves. Passing over the consideration of the various processes of dealing with sewage, which have been so often discussed—the cesspool, pail, dry-earth and water-closet systems; the Native Guano, Phosphate Guano, and other chemical processes; irrigation, intermittent filtration, etc., which were all treated of in the voluminous Reports of the Rivers Pollution Commissioners, Mr. Whitaker remarked that the sewers proper of any town could be laid out in an endless variety of ways, often, even, differently in the same town, their position and direction depending almost entirely on the levels of the streets under which they passed, and the situations of the valleys, rivers, or other adjacent watercourses. Sewers having to pass over or under rivers often materially influenced the general laying-out of the system adopted, but the most important matter to be considered by the engineer, in nine cases out of ten, was the position of the outfall, or locality of the ultimate discharge of the sewage before its final disposal. The laying-out the sewers of a town was a comparatively easy matter, though of course it should always receive most careful attention, as from the number of the town sewers their judicious arrangement must materially affect the cost of any work of town drainage. The determination of the position of the outfall was

*A paper read before the Civil and Mechanical Engineers' Society, by Mr. C. W. Whitaker.

often a matter of the greatest difficulty, and should never be settled upon without grave consideration and a thorough investigation of the locality. Time was not wasted, but well-spent, if many days or even weeks were occupied in arriving at a satisfactory solution of the difficulty. Available sites in the neighborhood should be visited, their situation with respect to the town considered, the direction of future building sites, the levels, soils, and surface formation inquired into, among various other matters, differing according to circumstances. In some cases the outfall would necessarily be far distant; sometimes it might be close to the town. At times the sewage might be conveyed away by gravitation; at others this was impossible, and pumping had to be resorted to. Obstructions and difficulties of various kinds would present themselves from time to time, and would have to be overcome by the tact and judgment of the engineer. With regard to the surface drainage, the author was of opinion that, as a rule, it was advisable to admit no waters—other than sewage waters for flushing—into the sewers. Generally, old drains and watercourses might be made available as carriers of rainfall to the natural outfall, and where not available new drains should be provided for the purpose. Where pumping was required this separation became almost a necessity. True, we had an example to the contrary at our doors; but sanitary engineering was a progressive science, and without describing in detail the results of working of the Metropolitan Main Drainage, he ventured to say that the engineers who laid out that system would never have designed it as it is, had they known what they have since learned. He ventured to predict that at no very distant day these very sewers would be used for sewage only, a new system of drains being constructed for the surface water, etc. With respect to the question of the sizes of sewers for small towns, it might safely be said that pipe sewers might for the most part be made available in all cases up to 10,000 inhabitants. He had never had the courage to propose in any street a pipe sewer of less diameter than 6 in., though he saw no reason why, when the gradients were good, 4 in., or even 3 in. pipes should not be laid down. He was inclined to think that in most towns the pipe sewers were constructed far larger than they need be if properly laid. In many cases the sum available for the work would not permit of sufficient proper supervision to insure the laying and jointing of every pipe perfectly firm and true. Nor was it possible to pick and select the good pipes and discard the bad ones, so as to insure perfect success. It might be asked—"Why not, if your specification is properly drawn up?" There were many reasons why it was difficult to carry out the letter of a specification in such instances. In small towns these works were usually let to the man who sent in the lowest tender, when, if he had respectable sureties, no amount of remonstrance from the engineer would avail to cause the man who really sent a respectably-priced tender to be chosen. The lowest tender got the job, and the contractor could not possibly do the work without losing money, unless he got his materials cheaply. The best pipe makers would not supply him without a considerable moiety of the cost being paid before delivery of the pipes. This he could not do, as he generally had to scramble on to the first instalment before he could pay anybody. Therefore he had to go to some second-rate maker who would give him credit for the pipes. If the engineer was a Shylock, and would have his bond, the contractor appealed to the Board, who, not knowing or not appreciating the difference between a good pipe and a bad one, let the man off, and allowed twisted, oval, or any sort of defective pipes to be laid. Another obstacle to laying out a system of pipe-sewers of sizes more nearly theoretically correct than was usually the case, consisted in the large differences in the sizes of the pipes as they had now become established by the pipe makers. There were pipes of 4 in., 6 in., 9 in., 12 in., 15 in., and 18 in. diameter, representing areas respectively as 16 to 36, 81, 144, 225, and 324. Mr. Whitaker said that what he should like to see done, and what he had often wished to have the opportunity of carrying out, was to have pipes made by the best makers (say Doulton), of small size (for the larger sizes were so difficult to make perfectly true), laid by good workmen, and well bedded and packed in their places, and with clean and smooth cement joints to each. And, in addition, he would like to have 5 in., 7 in., 8 in., 10 in., 11 in., 13 in., and 14 in. pipes, so that he could lay down a sewer of the capacity it ought to be (according to the inclination) to

act as a carrier for the maximum quantity of sewage that its drainage area and population could ever bring to pass through it. But he was afraid that the manufacturers would not countenance the innovation as to the smaller gradations in the sizes of pipes, and pipes of these sizes would be charged treble or quadruple their real value, as a "purpose-made article." Mr. Whitaker then proceeded to give an account of the drainage works carried out from the plans of Mr. Perrett and himself in the small town of Uppingham, in the county of Rutland. These works consisted of an intercepting pipe-sewer about a mile in length, with short branches, air shafts, ventilators, descending shafts, etc., and a short piece of outfall pipe-sewer leading to the settling tanks, etc., at the fields laid out for irrigation. The total cost was estimated, at the time the plans were approved (viz., August, 1871), at £12,000; but the Board preferred (as such Boards usually did) to do the thing piecemeal, and let the drainage be done first. The tender for this part of the works was let in March, 1872, for £596—the lowest tender. Some extra works brought the total cost of this part of the scheme up to £657. About 50 acres east of the town were found to be available for irrigation, but of these it was proposed to lay out only 25 until the entire house drainage should become connected with the main sewer, and cesspools abolished. The area ultimately laid out was, however, only 15 acres. In that portion of the land nearest the tanks there was a very light soil overlying a loose stratified rock—very hard grit, called "Kale" in the locality. Further on this dipped, and was overlaid for a considerable depth by a stiff blue clay. The entire area of the land was laid with 3 in. and 4 in. subsoil drains, running north and south, 30 ft. apart, at depths varying from 2 ft. to 4 ft., and in some places 5 ft. or 6 ft. These were connected with a 6 in drain at the bottom, delivering the effluent water, after passing over and through the soil, into the brook. The surface of the land was laid with half-round 9 in. tile carriers, in lines about 50 ft. or 60 ft. apart. At the end of the outfall there was a small pit or chamber, with two wooden penstocks movable by hand, to turn the sewage into either tank. The tanks were in duplicate, the one being cleared out while the other was filling. They were built of 14 in. brickwork with 4½ in. brick-on-edge paved floor laid on about 12 in. of Portland cement concrete, the whole interior surface being rendered ¾ in. thick with Portland cement and sand in the proportions of 2 to 1. At the further end of the tanks a shed was built, with paved and rendered floor similar to those of the tanks. Here were carted ashes, street-sweepings, dry earth, etc., and when the liquid sewage had run off on to the land, the solid residuum was passed through an opening in the end wall of the tanks on to the floor of the shed, and mixed with the ashes, etc., the mixture being used as a top-dressing for the land above the tanks. A special arrangement of cast-iron vertical telescopic pipes was adopted to insure the equable flow of the sewage from the tanks. In each tank there were three vertical screens or strainers to collect as much of the solid matter as possible, though the greater part sank to the bottom in the form of thick black mud. The ordinary discharge of sewage amounted to about 6,000 gallons every 24 hours, but a large majority of the houses in the town were not yet connected with the drains. The application of the sewage to the land had greatly increased the soil's power of production. As carried out, the total cost of the works had been £1,770, made up of the following items:—Drainage, £657; supervision of ditto, £73; disposal of sewage, including tanks, shed, and laying out land, etc., £860; supervision of ditto, £60; and engineering charges and expenses, £120. In order to complete the sewerage system throughout the town, and make the remaining portion of the area proposed for irrigation suitable for the reception of the sewage, a further sum of about £1,200 would have to be expended, making an ultimate total of £2,970 as the probable cost of the entire work of town drainage and sewage disposal. There were portions of the irrigation contract that could not be estimated on as to amount, such as the number of the carriers required, the subsoil drains, and trimming the surface, etc. These items of variable work were therefore tendered for at per yard, as follows:—Excavation and trimming surface of ground, at 7d. per yard cube; 9 in. half-round tile carriers, at 1s. 7d. per yard run, laid; 3 in. subsoil drains laid complete, at an average depth of 3 ft., including filling-in and every expense, 7½d. per yard run; 4 in. ditto, ditto, 9½d. per yard run; 6 in. ditto, ditto, 1s. 4d. per yard run; 9 in. ditto, ditto, 2s. per yard run. The tanks and mixing-shed were

tendered for at £127 ; 12 in. stoneware pipe outfall, jointed in Portland cement, at 1s. 9d. per foot run ; and 6 in. ditto, jointed in clay, at 1s. per foot run.

DISCUSSION.

The President, in inviting discussion, after pointing out the great importance of the subject of the drainage of small towns, said that it seemed to him that the 3 in. pipes referred to by Mr. Whitaker as having been used at Uppingham were very small indeed for a drain, for even in putting up a vertical soil-pipe in a dwelling-house no one ever thought of using less than a 4 in. pipe. It seemed to him that to lay down a 3 in. horizontal drain was "tempting Providence."

Mr. B. Haughton could have wished that Mr. Whitaker had touched at greater length upon the vexed question of sewage irrigation. At the present time there was an Act of Parliament which made it punishable for any one of the towns lying within reach of the Thames water-shed to throw their sewage into that river. But at present what were they to do? There were some half-a-dozen systems for getting rid of sewage before the public, but he was quite satisfied that no one of these was thoroughly sufficient for its object. It was not at all clear that sewage irrigation would do all that was claimed for it. At Barking there was a fine farm of about 300 acres, where the sewage of London had been experimented with for some years ; but if sewage irrigation was such a great success as it was said to be, why had not the farm been enlarged from hundreds to thousands of acres in extent? One of the greatest objections to sewage irrigation was that the quantity of sewage to be delivered upon the land was constant, whereas in some months of the year vegetation would absorb a much larger quantity than at other times. The sewage was obliged to be put out on the land whether it was required or not, and the consequence was, that the soil at times became saturated with fœculent matter. Some engineers said that this difficulty did not exist, or that if it did it could be overcome, but he was not at all satisfied as to this. It was quite clear that we had not yet arrived at a thorough solution of the sewage question. There was a very wide field open to engineers for invention, and whoever succeeded in thoroughly solving the question, might anticipate an ample reward. Birmingham, with its 450,000 inhabitants, after having gone to great expense in arranging for the disposal of its sewage by irrigation, was summarily stopped by the action of Sir Robert Peel and Sir Charles Adderley, and at present really did not know what to do. He believed that at Birmingham they had now constructed three or four subsiding tanks, getting rid of the solid matter as best they could. In one of the eastern towns (Lincoln, if he remembered rightly) they had tried the system of filtration, and had succeeded in producing an immense quantity of black fœculent matter, which they could not get anyone to take away on account of its worthlessness as manure.

Mr. W. Meakin thought it questionable whether sewage could be poured upon land in frosty weather (after passing through, in some cases, a long extent of sewer) with sufficient internal warmth to enable it to be taken up by the soil before freezing. Once the sewage was absorbed by the land, however, there was no doubt that its fertilizing properties would be stored up until the spring, when most required. There was, however, hardly any room for doubt, where the physical conditions were favorable, that in irrigation was to be found the real solution of the sewage question, rather than in the elaborate systems which had been experimented upon in some places. Mr. Haughton had rather understated the difficulty in which Birmingham found itself. It had not only been prevented from going on with the work of irrigation, but it had also been forbidden, by an injunction in Chancery, to continue to pour its sewage into the watercourses into which the sewage now went. It had, of course, been found impossible to enforce the order of the Court of Chancery. He agreed with the President in thinking 3 in. horizontal drain-pipes too small. It was surprising that the rude and primitive way in which drain-pipes were laid was allowed to continue in use in the present day. The method of making the joints, when well carried out, was, of course, perfectly sound, provided that the joints were never disturbed; but this could not be insured in all cases.

Mr. G. W. Usill could not agree with Mr. Haughton in saying that the sewage question had not been solved. True, it had not been solved so far as every town was concerned; but there was but one proper method of disposing of sewage, viz., by turning it upon the land. All towns might not be so situated as to make it easy to dispose of its

sewage in that way, but in all but exceptional instances irrigation was the only possible system, and, with the exception of General Scott's method, no other system whatever had shown any symptoms of success. If the evidence of our first professors of chemistry was to be believed, there was no chemical means at the present day which would solve the question. Several of the processes would allow of the sewage water being rendered as clear as crystal, notwithstanding that it would still contain the germs of disease. It seemed part of the economy of nature that the sewage should go to the land, for that which was the bane of the human system was the food of the plant. Of course, in some places where there were physical difficulties in the way of irrigation, some one or other of the precipitation processes might be desirable. After tracing the history of the A B C process, which he characterized as a notorious failure and worse, the speaker said that one of the most successful of the precipitation processes was the milk of lime process. Having referred to the alacrity with which local boards and vestries seized upon the slightest pretexts for shelving the sewage question, Mr. Usill strongly denounced the way in which the Richmond sewerage competition had been conducted, and concluded by pointing out the sheer waste involved in pouring into our rivers thousands of tons of valuable matter, for which the land was absolutely crying out, and all this waste was incurred because local boards would not incur necessary expenditure for utilization works. It was a matter of primary importance that the sewage should be disposed of, whether at a commercial profit or not.

Mr. W. F. Butler was also unable to agree to Mr. Haughton's remark, that the sewage question had not been settled. The Rivers Pollution Commission had reported that irrigation was the only successful means known for the purification of sewage. Dr. Frankland had said that there was no chemical means at present known by which the sewage of towns could be purified. General Scott did not profess to purify the sewage; his process was put forward merely as a means of utilizing waste matter. The speaker then touched upon the importance of flushing drains and sewers, especially where the fall was not great, and described an invention which he had that day seen, of Mr. Rogers Fields', which he considered admirably adapted for the purpose. It consisted of a tank or barrel, made of cast-iron or stoneware, and holding 25 gallons and upwards. On the top of this tank was a cast-iron grating, under which was a trap for preventing the return of offensive smells. The house-slops, or other waste waters, were passed into the tank through the grating and trap, and when the tank was full, a siphon at the end, communicating with the drain, was called into action, and discharged the whole of the contents of the tank into the sewer. The invention was entirely self-acting, and required no attention whatever. Though intended for house purposes, the speaker considered it specially suited, on a larger scale, for flushing sewers. The cost of the apparatus varied from £2 to £5. Reverting to the subject of sewage irrigation, he wished to remark, on the authority of the Rivers Pollution Commission, that it was a chemical as well as a mechanical process. The ground had the property of storing up within itself and containing for almost any length of time the poisonous particles of sewage matter. Providing the soil was duly aerated, the oxygen of the air converted the ammoniacal matters contained in the sewage into substances perfectly harmless, and the process went on whether there was vegetation on the ground or not. This had been abundantly shown by passing sewage through a sufficient layer of gravel, quite irrespective of vegetation. In conclusion, Mr. Butler pointed out that the death-rate of Birmingham was from 4 to 6 per thousand higher than that of any other large town, and he thought that it was lamentable that a town of 450,000 inhabitants should have disease and death forced upon it by Parliament, merely because of the sentimental grievances of two members of Parliament, who happened to be large landowners in the locality.

Mr. E. Perrett observed, that in carrying out such works as the drainage of small towns, two sorts of engineering were required—the engineering of matter and the "engineering" of men. The latter was more often the most difficult of the two. Most of the successful engineers of the day knew how to "engineer" men better, perhaps, than they knew how to engineer matter. As Mr. Whitaker's partner and coadjutor in carrying out the works at Uppingham, he might say that the contract was absolutely executed for less money than the engineers had stated it would cost.

He thought that Mr. Butler had shown that the supposed difficulty of irrigating with sewage in winter did not exist. When the ground was laid out, as at Uppingham, any portion, or almost any portion of it, was capable of being used as an intermittent filter, and the reservation of a small portion of the land on a large sewage farm would entirely obviate the difficulty referred to. Lime had been justly described as one of the best precipitants, but it had the great disadvantage of destroying what little fertilizing properties the solid part of the sewage possessed. Although the A B C process had been exorbitantly overrated, it was, he believed, the best of the precipitating processes. It was constantly said, that by all means sewage must be utilized; but he would ask, if it cost more to utilize it than to destroy it, why utilize it? If it cost £10,000 a year to irrigate with sewage—and £10,000 spent in guano would do far more good for the farmer—why should the sewage be utilized? The 3 in. pipes referred to, were not for the sewage; they were simply pipes for draining away the effluent water.

Mr. Brewster asked what had been the effect upon the residents on or near to an irrigation farm using the sewage from a town which had been visited with an epidemic?

Mr. Whitaker, in replying, said he thought the success of sewage-irrigation had been demonstrated beyond a doubt. As to the small pipes to which the President had referred, perhaps no one would have the temerity to lay a 3 in. drain-pipe as a sewer; but if the inclination were sufficiently good, and the joints well made, he saw no reason why it should not take the sewage of one house or of a small court, as well as a 6 in. pipe. It should be remembered that the solid excrementitious matter became broken up and disintegrated on leaving the soil-pans, and the chance of its choking up the pipes was very remote indeed. Irrigation was not, perhaps, the panacea for getting rid of sewage in every case; but where it was not possible, intermittent filtration might be resorted to with advantage. All soils, according to Dr. Frankland, were equally well suited for the purification of sewage, although with some the operation was quicker than with others.

At Conventry it had been found that no inconvenience whatever resulted on the sewage-farm during the prevalence of frost. Probably at Harrow there was only a small stream trickling from the outfall, not sufficient in volume to resist the frost. In conclusion, Mr. Whitaker said that while he would not attempt to lay down drain-pipes theoretically correct, he thought it was desirable to endeavor to approximate more nearly to accuracy than was the case at present; rule of thumb was more in the ascendant than it should be. In answer to Mr. Brewster's question, Mr. Whitaker said he had never heard of any injurious effect resulting to the residents of a farm irrigated with sewage from a town visited with epidemic disease.

THE SUCCESSFUL UTILIZATION OF BLAST FURNACE SLAG.

From "The Mining Journal."

Among the many efforts made at the utilization of waste vitreous products, none have been more successful than those that have just assumed a practical and definite shape on Tees Side. The blast furnaces of the North of England now produce about 2,000,000 tons of pig-iron per annum. For every ton of pig-iron made there is 1½ ton of slag, so that at the present time the waste vitreous products of northern metallurgy must be accumulating at the rate of about 3,000,000 tons per annum. It is calculated that about 25,000,000 tons of slag have been produced in the North of England since Messrs. Bolckow & Vaughan first commenced to smelt the iron ore of Cleveland, in 1851. This immense volume of material necessarily covers many acres of ground, which could otherwise be rendered available for industrial or agricultural purposes. Every establishment where smelting operations are carried on must have its slag-tip. It is as necessary as the blast-furnace itself; and it often happens that this slag-tip takes possession of ground that can ill be spared. Some of the principal works in the Middlesborough district, such as those of Bolckow, Vaughan & Company, Hopkins, Gilkes & Company, and Stevenson, Jacques & Company, have

recently gone to the cost and labor of removing their slag to a considerable distance, rather than allow it to occupy land which is necessary for building or other purposes, and for which they can realize a high value. Such cases are, however, exceptional. As a general rule, a high slag heap will be found adjacent to all smelting establishments, and where the area of such works is of limited extent, the proprietors are always perplexed with the question of how the slag is to be got rid of when the land available for its deposit is entirely filled up. It is, probably, not too much to assume that each of the forty different firms connected with the Cleveland district, has on an average 10 acres of land appropriated for the deposit of slag; and if ways and means of profitably and successfully utilizing these waste vitreous products could be discovered, these 400 acres would be useful and productive, whereas they are now useless and unproductive. But this is not all, nor even the worst of the matter. The removal of the slag from the blast-furnace to the "tip" involves the employment of a regular staff of men, who are as permanently attached to all smelting establishments as chargers or keepers. These men are paid a high rate of wages, and their employment is a regular and unavoidable tax upon the ironmaster. In the North of England this tax is more severely felt than elsewhere, because on account of the poorness of the ores of Cleveland, which do not contain more than 28 to 34 per cent. of iron, the educt of slag is much more considerable than it would be in districts or at works where the ores used contained from 40 to 60 per cent. of metal. To the North of England, therefore, this question possesses an amount of interest and importance such as it cannot have in any less extensive centre of metallurgical operations. Attention has again and again been called to the practicability of utilizing this scoriæ, and plans without number have been proposed and acted upon with that end in view. But none of these plans had the elements of permanence about them, nor were any of them so comprehensive as to include one-half the works in the district. The most, indeed, that has ever been attempted in this direction has been the construction of the Tees Breakwater by the Tees Conservancy Commissioners, who will have used over 3,000,000 tons of slag in this great undertaking when it is completed. The problem of the permanent and complete utilization of scoriæ remains, or did until lately remain, apparently as insoluble as ever. We are glad, however, to be able to say that there is now every likelihood of this prolific source of waste and difficulty being removed. Competition, as our copy-books used to tell us, is the soul of business, and the fact of competing plans for the utilization of clay having been projected, will stimulate the efforts of those who are endeavoring to effect the accomplishment of this desirable end.

Along with some of the Directors of the Tees Scoriæ Brick Company we had an opportunity a few days ago of witnessing the operation of Mr. Woodward's patent plan for the manufacture of bricks from slag. It was at the Clay Lane Works of Messrs. Thomas Vaughan & Company where the manufacture was shown. Here there are some kilns erected, with other necessary appliances for the process, which commences with the removal of the slag in bogies, or otherwise, to the vicinity of the ovens. The slag is here allowed to run into moulds, which are filled as rapidly as they can be removed, while the slag is yet in a hot state, to the moulding oven or flue. After they have remained here for a certain period, not exceeding 30 hours, the bricks are found to have a fine hard skin, and are otherwise equal to any ordinary paving or fire-bricks. There are features of Mr. Woodward's process susceptible of improvement; and where there are defects in respect of mechanical details they will, doubtless, be remedied in course of time. But all this has hitherto been subordinate to the great question—is it possible to make from scoriæ, bricks that can compete with ordinary bricks as regards quality, and at the same time prove economically and commercially successful? This question Mr. Woodward has practically answered in the affirmative. For paving and channelling purposes, nothing could beat the bricks we saw produced by his process. They were quite equal to such bricks as are now sold in the market at £3 to £4 per 1,000, and they can be made to sell at a profit for 50s. Indeed, a lot of them has been sold at the latter figure to a Stockton firm, which has expressed the utmost satisfaction with the purchase.

The specific gravity of Cleveland slag varies from 2.9 or 2.10 to 2.6, or even less in varieties that are full of minute vesicles. The mean specific gravity of all the differ-

ent slags taken together has been set down at about 2.8, so that the mean weight of a cubic foot is 192 lbs. or 11.6 cubic ft. per ton, being thus of about the same density for building purposes as basalt or granite. Hence the greatest speculative objection urged against the employment of slag for building purposes arises from its weight; and it would be useless to deny that this is to a large extent a rational and fair objection.

Slag bricks cannot be made so light as ordinary red or fire-bricks, unless they were exposed to chemical treatment, which is calculated to impair their efficiency and increase their cost. But seeing that a high quality and cheapness of production are combined in the scoriæ bricks, these advantages ought to offer full compensation for the difference of weight. We had the opportunity of seeing the relative weight of slag bricks and clay compared at the Clay Lane Works, and the result showed that on an average the former exceeded the latter by about 2 lbs. Thus, an ordinary fire-brick weighs about 9 lbs., while a slag brick suitable for the same purposes will weigh about 11 lbs. The weight of a red brick is about 7 lbs., while a slag brick suitable for ordinary purposes is about 9 lbs. With this single exception the slag brick is in all respects equal, if not superior, to the other. It will bear a much greater strain, for we ourselves tested its hardness to this extent; and it is allowed to be quite as durable. Nothing, therefore, seems wanting but energy and enterprise to take up this new industry, and carry it on to such an extent as will render it commercially successful.

It would be unfair to withhold allusion to the efforts that are now being made by the Tees Slag Company to attain the utilization of that product. This company has purchased the patent right of Mr. Wood and Capt. Bodmer, and are about to erect works near to the Tees Ironworks for the manufacture of building materials on a large scale. It remains to be seen which of the two processes will be the most successful from a commercial point of view; but both have demonstrated the practicability of the end aimed at. At the next meeting of the Cleveland Institute of Engineers Mr. Wood will read a paper on his process, and from that and the discussion thereupon we are likely to glean some statistical data. It is the eve of a revolution in the metallurgical industry of Cleveland, for if the two companies now aiming at the utilization of slag accomplish all their intentions, they will not only induce others to enter the field, but they will succeed in making slags, now worth less than nothing, a commodity of value to the ironmaster, and so cheapen very materially the cost of his manufacture.

ON THE APPLICATION OF SOLAR HEAT AS A MOTOR FORCE.

(G. A. BERGH in "Poggendorff's Annalen.")

From "The English Mechanic and World of Science."

That the heat of the sun may be transformed into mechanical force no one can doubt; for we see daily what masses of water solar heat raises into the air, to be again precipitated to the earth, and we know what an enormous mechanical force is here represented. Further, we know that solar heat is the cause of motions of the atmosphere, that plants under its influence form out of the carbonic acid of the air, an organic substance richer in carbon; that plants which grew in earlier times, under the influence of sun heat, were transformed into coal and peat, whose combustion now yields heat to drive our engines, which is simply the solar heat returned.

But while solar heat is the cause of nearly all mechanical force developed on the earth, we have yet hitherto known of no means whereby it may be directly utilized for mechanical work. It has been proposed, indeed, to employ solar heat, concentrated by lenses or mirrors, for driving a steam or caloric machine. These machines, however, are not suited for this, as they involve too great a waste of heat. Moreover, in concentration a large quantity of heat must be lost. These circumstances, as also the fact, that the concentrating apparatus must always be moved according to the motion of the sun, have rendered such machines impracticable.

Sun machines must be so arranged, that the solar heat absorbed by a given surface may, without too great waste of heat, be directly transformed into mechanical work.

We propose to inquire how such a machine may be had.

It is known that the arrangement of machines, which serve for the tranformation of heat into mechanical work, rests on the principle that a liquid or gaseous substance, acted on by the heat, undergoes a molecular change, through which a certain mechanical force is developed. The changes of solid bodies, under influence of heat, are too small for transformation of the heat into mechanical work, or to render them means of movement, although through such molecular change a certain mechanical force is developed. Gaseous bodies have been applied as means of movement in the caloric and gas machines; but, with the small differences of temperature which occur in some machines, they cannot be employed as such, with advantage. Thus nothing remains but to employ a liquid; and it must be one whose boiling-point is very low. We know that the great expenditure of heat in steam-engines is due, in great part, to the high boiling-point of water. The higher steam-pressure we have in the boiler, the greater is the quantity of heat transformed into mechanical work. Hence, if we had a liquid which, at ordinary temperature, behaved like water at a high temperature, this liquid would be a suitable means of motion for a sun machine. There are several such liquids, *e. g.*, sulphurous acid, methylic, chloride, methylic ether, etc. Of all these, sulphurous acid best deserves attention, as it has several useful properties for the end in view. It is not too difficult to condense, and it can be got at a moderate price. The keeping of it presents no difficulties, and it may quite well be put in ordinary steam-boilers. Now, we have got the principle on which we must construct our sun-machine. Conceive a vessel, filled with sulphurous acid, exposed to the sun's rays; the tension of the sulphurous acid vapor, if the temperature of this vessel exceeds that of the surrounding air by at least 10 deg. to 20 deg., must be from 1 to 3 atmospheres higher than that of the sulphurous acid vapor in another vessel B, similarly filled with sulphurous acid, but which has only the temperature of the surrounding air. We can thus arrange an engine which agrees in principle with the steam-engine with merely this difference, that the water is replaced by sulphurous acid, and the fuel by the solar heat; while the vessel exposed to the sun's rays represents the steam-boiler, the vessel kept at ordinary temperature may represent the condenser. The sulphurous acid condensed, after doing work in vessel B, could easily be driven back by a force-pump into the boiler representing vessel A. The capability of work of such a machine must naturally increase with the amount of heat communicated to vessel A, or be proportional to the surface exposed to the solar rays.

If, now, we conceive, a factory or shop, the roof of which is covered with vessels containing sulphuric acid, and which is furnished with a sun-machine, made on the above principle, such a machine might, indeed, work while there was sunshine; but in default of this, the establishment would be brought to a standstill. True, the solar heat might be replaced by the heat of the air, if the temperature of the air were pretty high, and one had at hand a cooling substance like ice. But as this is not always the case, the establishment should have, besides the sun-machine, an apparatus which might "store up" some of the work done by this. As such, Natterer's apparatus for condensing carbonic acid, might, with great advantage, be used. If a supply of carbonic acid were kept in a large gasometer, like those in ordinary gasworks, the Natterer apparatus might be fed from this. In a wrought-iron vessel thus filled with liquid carbonic acid, we should thus have an enormous store of mechanical force, which might be made to replace the action of solar heat in the sun-machine, partially or wholly. After work done, the carbonic acid, become gaseous again, might be collected in the gasometer. Or, again, the sun-machine, while in action, might drive an ice-machine, and might, in default of sunshine, profit by the ice it had produced, for maintenance of its working.

We thus see that from the present standpoint of science, it is possible to construct a constantly working sun-machine.

SERVIAN RAILWAYS.—The principal conditions proposed for the construction of a railway in Servia are as follows: The concession is to be granted for a term of 50 years, but the Government is to have the option of purchasing the line at the expiration of 20 years. The undertaking is to be called "The Servian State Railway," and it is to have a double line of rails.

ON A METHOD OF REFINING AND CONVERTING CAST IRON INTO IRON OR INTO STEEL.*

By Sir FRANCIS CHARLES KNOWLES, Bart., F. R. S.

From the "Journal of the Society of Arts."

The object of this method, generally stated, is the refining or purification of cast iron from sulphur and phosphorus, and its conversion into iron, or into steel, of various qualities, according to the nature of the metal treated, with an increased yield of malleable iron or steel per ton of metal.

The ordinary puddling furnace is at one and the same time time a generator of gases and a converting vessel, of simple construction requiring no motive power, and readily admitting of the application of manual labor to conduct the process which it is intended to perform. But, on examining more closely its operations, we shall perceive that the above advantages are more apparent than real. The gases generated depend for their production on their own combustion, and the greater part of the heat which they evolve goes to heat the chimney stack, and to create the necessary draught, after which it is wasted. That part of it which is applied to the metal is applied under a great disadvantage, and by the aid of the most severe form of manual labor; and the chemical action of the heated air, in its oxidizing of the impurities and of the carbon of the metal, is discontinuous and uncertain, and involves, besides, the needless oxidation of much of the metal itself. Both the heating flame and the re-agents, where used, are applied on the surface of the bath, which is protected by a layer of liquid scoriæ of great specific heat, except when the rabble exposes the metal, while the re-agents are diluted or decomposed by the scoriæ. These disadvantages become more sensible in proportion to the degree in which other re-agents than heated air are to be applied to the purification of the metal. The present is an attempt to devise a method which should be free from the waste of heat and material which takes place not only in puddling, but also in methods of more recent origin.

The means adopted are:—

1. The separation, as far as possible, of the heating process from the chemical process.

2. The securing of a highly basic scoria —or cinder—of not exceeding 30 per cent. of silica, by means of finery and converting furnaces in which that acid is not present.

3. The employment of caustic soda in conjunction with pure and rich oxide of iron in the elimination of the sulphur and of the phosphorus.

4. Where pure cast iron is treated, and superior iron or steel is to be produced, the use of nitrate of soda, or of permanganate of soda.

The source of heat employed is the complete combustion of gases rich in carbonic oxide gas combined with heated air to 500 deg. C., in due proportion. The metal being first melted in a cupola with pure dense coke or anthracite coal, the resulting gases are collected and utilized by freeing them from carbonic acid (if any), and enriching them with pure carbonic oxide gas, cheaply produced, until a compound is obtained of from 70 to 80 per cent. of carbonic oxide gas and 30 to 20 per cent. of nitrogen; or, if a higher heat be required, a larger charge be treated, and a more speedy operation be the object, the cupola gases are used to heat the retorts, and pure oxide of carbon, as described below, is generated for the purpose.

In the former case a temperature of combustion of 2,500 deg. C. and upwards is obtained, in the latter one of 2,979 deg. C., without taking into account the heat (500 deg. C.) of the air and gas, and the pressure, as it is easy to calculate from the data of the case.

The gas (in either case) being mixed in the condenser with hot air in the proportion to insure the production of only carbonic acid gas and nitrogen by the combustion, with no excess of air, is blown into the body of the metal bath by appropriate apertures at the level of the hearth or sole, giving, therefore, a neutral flame, while the carbonic acid gas and the nitrogen rising from below with force in all directions, and, aided by the natural lightness of the hotter metal, stir, agitate, and mix the particles of the metal, and so bring them all successively

* A paper read before the Society of Arts.

into contact with the re-agents employed, and with each other, doing in fact the work of the puddler. The iron can be "balled" by simple machinery. The blast is urged, in the Bessemer plant, by an engine of from 250 to 300 horse power, adapted to appropriate sucking and forcing pumps, and the gaseous mixture enters the bath at a pressure of about 1.2 atmospheres. From this it appears that in practice there is an injection of about 1 cubic metre, or of something less than 35.5 ft. per second

The gases are collected in gasometers, the hot air in the usual apparatus. The stopcocks in the leading pipes are so regulated by a graduated scale as to allow the proper volumes to pass under the given pressure into the condenser.

The carbonic oxide being thus burned with a neutral flame, the carbonic acid gas that is formed and the nitrogen quit the surface of the bath at an intense heat (2,150 deg. C., subject to radiation and conduction), which heat may be easily utilized. If the gaseous product of the combustion be passed through a kiln or retort of anthracite coal or of coke, the carbonic acid will take up a second equivalent of carbon, and one volume of it will yield two volumes of carbonic oxide, which absorb 2,400 units of heat per kilo. of weight, the nitrogen remaining constant. A computation given below will show that the resulting gas contains about 47 per cent. of carbonic oxide. If, after a second combustion this conversion of $C O_2$ into C O be repeated. the proportion of C O to N will fall to 39.71 per cent., and so on in a decreasing ratio, until we arrive at 34 per cent., the ratio of the cupola gas. The carbonic acid may thus be used as an economical beast of burden to carry fuel to its destination. These converted gases may be used first to heat the generating retorts, and may finally pass into the flues of the boilers, which, with good management, ought to be heated without any other fuel. (If desirable, the nitrogen may be freed from the remaining carbonic acid gas and obtained pure, in which state it may possibly be turned to good account in the preparation of cyanides.)

Enough has been said to show, as the degree of heat generated is indisputable, that the sufficiency of the finery or converter to resist the intense heat evolved and the corrosion by the reagents, is the main condition of the success of this process in the physical and chemical point of view. The question of its commercial success will be considered subsequently.

In order to insure this condition, the finery or converter is made of pieces of cast metal, so constructed that the tuyeres may form one piece with the casting itself. In fact, they are bored out of the solid casting itself, and the apertures are countersunk to meet them at the level of the hearth. The whole is bound together by an exterior jacket of well-riveted boiler-plate, so that in case of an accidental fracture of the castings there may be no danger of the access of water to the molten iron. The whole finery (or converter) is enclosed, and well supported in an iron tank or cistern, through which run currents of cold water adequate to prevent fusion of the sole or walls of the finery. In order to protect from corrosion the interior of the finery, which the re-action might cause, a basic paste is formed of protoxide of iron, or as nearly such as may be, or of manganese, of Naxos emery or bauxite (an aluminous mineral used in France for making aluminium), and caustic soda in small quantity. This is laid on in thin layers, which, when gently dried, are successively reduced to a state of pasty fusion by the flames of the gases, so that the particles of the mixture may cohere, and furnish a lining of adequate thickness in the form of a semi-enamel or glazing. The best Naxos emery is now quoted at £12 per ton in the stone. This lining is so slowly fusible if the soda be not in excess (which economy alone will prevent) that it will last a long time, and cause but a trifling cost per ton of metal. So far as it is fused, being highly basic, it will be an advantage to the scoria, and it is a bad conductor of heat. Its basic nature is of great importance. It will be seen on reference to Baron Gruner's last pamphlet, "Etudes sur l'Acier et le Procédé Heaton" (Dunol, Paris), that he considered it as a *sine qua non* for the elimination of the phosphorus that the maximum dose of silica in the scoria should be 30 per cent.; and he cites, in confirmation of his opinion, Berthier's analysis of the only cinders which were found to contain phosphoric acid. The fulfilment of this condition would enable us to make at once good bar iron or steel from the oolitic iron ores of Cleveland, Northamptonshire, Lincolnshire, Belgium, and the North of France.

There remains only one more point to be considered, namely, the efficiency of the re-

agents, caustic soda, and the rich oxides of iron or manganese. As the former substance is costly, it must be used with due precaution against waste. Accordingly, where the metal treated contains much silicium, or where sand adheres to it from the casting-bed, it must undergo a preparatory refining with peroxide of iron alone, if possible, with the variety of red hematites (to be found in abundance in Devon and Cornwall), containing only carbonate of lime as its gangue. The silica, and much of the sulphur and phosphorus, being thus expelled, and the scoria being removed, the metal is to be treated with caustic soda and peroxides of iron free from silica. Manganesiferous spathose ore calcined, or calcined spathose ore, with the addition of from 5 to 10 per cent. of oxide of manganese, pure and rich magnetic ores, particularly iserine, which contains about 10 per cent. of titanic oxide, are the most valuable adjuncts.

It is hardly necessary to argue in a chemical point of view the superiority of these re-agents; if, indeed, there is room for comparison between the use of a pure detersive re-agent, and that of scoriæ already charged with the very substance which is to be expelled. But we need not resort to chemical affinities to establish this efficiency. Both nitrate of soda and caustic soda with oxides of iron have been tried in the common puddling furnace, and in the Heaton converter, and the scoriæ produced in the latter case, when tested by the analysis of the late Professor Miller, F. R. S., and subsequently by those of Baron Gruner, were found to contain phosphate of soda, while the metal had lost above 80 per cent. of its phosphorus, under the oxidation of the nitrate, and in presence of the alkaline base, which it is evident, as in other analogous cases in chemistry, had induced the combination of the phosphorus with the oxygen present in a nascent state. More than this, sodium was found in the metal, which both Professor Miller and Baron Gruner affirm forms volatile compounds with the residue of the phosphorus, and thus leads to a further cleansing of the metal in the ulterior stages of manufacture. The quality, moreover, of the iron produced by the author in his works at Flint with nitrate of soda, after treatment of the iron with peroxide of iron, aluminous kaolin, and lime, was extraordinary; for the metal treated was no better than a charge of three-fourths of the cheapest and most ordinary scrap metal with one-fourth of grey metal, made from a brown hydrated peroxide of iron (a decomposed spathose ore). Rivet rods made with it were tried in the factory of Portsmouth Dockyard, and were pronounced to be at least equal to best Low-moor or Bowling rivet iron. The author has samples, both of this and of iron made with oolitic ores without admixture, which speak for themselves.

The converter destined for casting steel, or homogeneous iron, is cast in one or two pieces, and has a similar jacket of boiler plate with a similar lining, or enamel. I is movable, so as to admit of being hoisted by a chain and pulley, and removed by a crane for casting or charging. The tuyeres are bored in flanges at the side, and communicate with an aperture at the bottom of the hemispherical, or hemiovoidal vessel. The whole, as in the case of the finery, is placed and firmly supported in a cistern or tank of running water. The casting may be conveniently made through the tuyeres themselves, and the steel is to be poured into moulds, just as in the method of Mr. Bessemer. The saving of wear, as compared with the wear of any finery or converter at present in use, must be very large, the wear in fact being confined to the enamel lining, which will in each heat become at once slightly viscous on the surface.

Such is the outline of this very simple process, and the author leaves it for consideration whether more heat is required to produce the mechanical power employed in it than now goes up the chimney of the puddling furnace, or would be required for any conceivable system of mechanical puddling.

It remains to exhibit the calculations which measure the quantities of the gases employed, their temperatures of combustion, and their effective heating powers; and their cost of production with the cost per ton of iron of this method of treatment.

1. To calculate the composition of the cupola gases, we may take 2½ cwt. per ton of cast metal as about the weight of coke or anthracite coal required to melt that ton. Let W^1 be the weight of carbon contained in this (which will vary from 91 to 98 per cent. in the anthracite coal). Then the oxygen required to form with this carbon carbonic oxide gas will be

$$\frac{8\,W^1}{6} = \frac{4\,W^1}{3};$$

and $$\frac{77}{23} \times \frac{4\,W^1}{3}$$

will be the weight of the nitrogen in the air which the blast supplies for it. Therefore, the compound gas of the cupola per ton of molten metal will be represented by

$$\left(W^1 + \frac{4\,W^1}{3}\right) + \frac{4}{3} \times \frac{77}{23} \times W^1$$

and the richness of this gas in carbonic oxide will be measured by the fraction

$$\frac{\frac{7\,W^1}{3}}{\frac{7W^1}{3} + \frac{4}{3}\frac{77}{32} \times W^1} = \frac{7\,W^1}{7\,W^1 + 4 \times \frac{77\,W^1}{23}} = \frac{1}{1 \times \frac{44}{23}}$$

$$= \frac{23}{67} \text{ or } 34.32 \text{ per cent.}^*$$

2. This cupola gas being given, and also a supply of pure carbonic oxide, in what proportion by weight must they be mixed in order to produce a gas consisting of 75 per cent. of carbonic oxide and 25 per cent. of nitrogen?

Let the weight per ton of molten iron of the cupola gas be called.

$$C = \frac{7\,W}{3} + \frac{4}{3} \times \frac{77\,W^1}{23},$$

and let x be the weight of carbonic oxide gas required.

Then, by the conditions of the question, we must have:—

$$\frac{34.32}{100} C + \frac{100}{100} x = \frac{75}{100} (C + x),$$

from which equation we deduce,

$$x = 1.627\ C, \text{ and } x + C = 2.627\ C.$$

we readily find—

$$\frac{7\,W^1}{3} = \frac{\text{cwt.}}{7.6700} \text{ and } \frac{4}{3} \times \frac{77\,W^1}{23} = \frac{\text{cwt.}}{14.6051},$$

whence we have value of

$$C = 22.3620 \text{ cwt., and } x + C = 58.745 \text{ cwt.}$$

Thus the carbonic oxide at our disposal will be $.75 \times 58.745$, or nearly 2 tons 4 cwt., the only part which is not waste gas being $x = 36.383$ cwt.

3. To determine the temperature of combustion of this gas, its initial heat and that of the air being 500 deg., our data are as follows:—One kilo. of carbonic oxide in burning evolves 2,400 units of heat, or calories, and the products of combustion are carbonic acid and nitrogen. The specific heat of carbonic acid is .216, that of nitrogen is .244. Of the proposed gas, $\frac{3}{4}$ kilo. are carbonic oxide, and $\frac{3}{4}$ kilo. nitrogen. It will come to nearly the same thing whether we consider the carbonic oxide and the oxygen and nitrogen to be heated to 500 deg., or the carbonic acid and the nitrogen be so heated. We have upon this data:—

$\frac{3}{4}$ kilo. $\times$ 2,400, giving out 1,800 calories.

To burn $\frac{3}{4}$ kilo. of carbonic oxide, we require $\frac{8}{14} \times \frac{3}{4}$ kilo. of oxygen, making $\frac{33}{28}$ kilo. of carbonic acid, and importing $\frac{7}{23} \times \frac{3}{7} = \frac{33}{23}$ kilos. of nitrogen from the air;

Thus the total nitrogen will be $(\frac{1}{4} \times \frac{33}{23})$ kilos. or $\frac{1}{92}\frac{65}{3}$ kilos.

The specific heats for 1° are:—

Of the carbonic acid gas $\frac{33}{28} \times .216 = .2546$.
" " nitrogen $\frac{1}{92}\frac{65}{3} \times .244 = .4110$.

Sum..... $= .6656$.

Therefore for $(t^\circ - 500^\circ)$ the number of degrees to which the products are raised, this sum will be—

$$.6656 \times (t^\circ - 500^\circ)$$

which is to be equal to the sum of the calories developed, that is—

$$.6656\,(t^\circ - 500^\circ) = 1800,$$

and for the temperature of combustion t°,

$$t = \frac{1800 + 500 \times .6656}{.6656} = \frac{1803.328}{.6656} = 2709^\circ \text{ C.}$$

(This does not take into account the effect of the compression.) Chevalier Bunsen made the temperature of combustion of pure carbonic oxide 3,042° C.; the above data give 2,979° C. The gas resulting from the first conversion of $C\,O_2$ in the above products into $C\,O$, viz., 47.09 per cent. of carbonic oxide gives a temperature of 2,221° C., independently of its initial temperature.

The cupola gas gives 1,900° C. nearly, which, it is evident, is more than is required to heat the retorts or the air.

4. The carbonic oxide being 75 per cent., and the nitrogen 25 per cent., if we put the former $= W^1$, we have the latter $= \frac{W_1}{3}$, and the composition of the gas will be denoted by $W_1 + \frac{W_1}{3}$. The oxygen required to burn this gas completely is

$$\frac{8\,W^1}{14} \text{ or } \frac{4\,W_1}{7},$$

* This agrees within a few hundredths with the result of direct analysis of generator gases.

1*st Combustion*—The CO_2 yielded is:—

$$W_1 + \frac{4\,W_1}{7} = \frac{11\,W_1}{7}$$

The nitrogen due to—

$$\frac{4\,W_1}{7} \text{ is } \frac{77}{23} \times \frac{4\,W_1}{7} = \frac{44\,W_1}{23} \times 7.$$

and the total nitrogen is

$$\frac{W_1}{3} + \frac{44\,W_1}{23}$$

1*st Conversion*.—By passage through the kiln of anthracite or coke.*

To form C O from $C\,O_2 = \frac{11\,W_1}{7}$ we must add to it of carbon $\frac{6}{22} = \frac{11}{7} \times W_1$; thus giving of C O the weight

$$\frac{11\,W_1}{7}\left\{1 + \frac{6}{22}\right\} = \frac{11}{7}\left\{\frac{28}{22}\right\} = 2\,W_1.$$

The composition of the gas will now be,

$$2\,W_1 + \frac{W_1}{3} + \frac{44\,W_1}{23}$$

and its richness in C O will be measured by the fraction—

$$\frac{2\,W_1}{2\,W_1 + \frac{W_1}{3} + \frac{44\,W_1}{23}} = \frac{1}{1 + \frac{1}{6} + \frac{22}{23}} = \frac{47.09}{100}$$

2*d Combustion*.—To burn this gas completely, the O required is—

$\frac{8}{14} \times 2\,W_1$, and the $C\,O_2$ produced is $2\,W_1$

$$\left\{1 + \frac{8}{14}\right\} = 2\,W_1 \times \frac{11}{7}.$$

The nitrogen corresponding to O in the air is—

$$\frac{77}{23} \times \frac{4}{7} \times 2\,W = \frac{44}{23} \times 2\,W_1$$

and the total nitrogen becomes—

$$\frac{W_1}{3} + \frac{44}{23}W_1 + \frac{44}{23} \times 2\,W_1 = \frac{W_1}{3} + \frac{44}{23} \times 3W_1.$$

2*d Conversion*.—To convert this CO_2 into C O, we require of O,

$$\frac{6}{22} \times \frac{11}{7} \times 2\,W_1$$

and the C O formed will be now,

$$\frac{11}{7} \times 2W_1\left\{1 + \frac{6}{22}\right\} = \frac{7}{11} \times 2\,W_1 \times \frac{28}{22} = 4\,W_1$$

The composition of the gas will be as follows:—

$$4\,W_1 + \frac{W_1}{3} + \frac{3 \times 44\,W_1}{23}$$

Its richness in C O is measured by the fraction

$$\frac{4\,W_1}{4W_1 + \frac{W_1}{3} + 3 \times \frac{44\,W_1}{23}} = \frac{4\,W_1}{4 + \frac{1}{3} + 3 \times \frac{44}{23}} = \frac{39.71}{100}$$

The law of the progression is evident, as well as the economy of the process. These gases may be used in heating up the metal bath, but they may be better employed for the retorts and the boilers of the steam engines. We may readily compute their temperatures of combustion, but it must be remembered, in employing the data above given, that, unless we take into account the temperature 2,150 deg. C., at which it will be seen they rise from the bath, as well as the specific heat of the fuel employed to give the additional equivalent of carbon, we shall have our results much below the actual temperature of combustion.

It might seem that there is a loss of heat in the conversion of the $C\,O_2$ into $C\,O_1$, one volume yielding two; but this heat 2,400, units for each kilo. of the gas, is in reality stored up and is given out again upon its combustion. This is to be borne in mind when we come to the conversion of the carbonic acid gas of limestone into carbonic oxide.

5. The blast engine of from 250 to 300 horse power, delivering at a pressure of 1.2 atmospheres, 1 cubic metre, or 35.3198 cubic feet per second, required the weight of carbonic oxide gas injected into the metal bath, the gas containing it (viz. 75 per cent. C O and 25 per cent. N) being combined with the weight of air due to complete combustion.

Let W_1 be the weight of the gas required, then is $\frac{W_1}{3}$ the weight of the nitrogen combined with it. Let—

s_1 = the specific gravity of W_1 = .9.708
s_2 " " " $\frac{W_1}{3}$ = .9.760
} the sp. gr. of air being 1.000.

As 1 cubic foot of air weighs 1.2 oz. avoir., if we make 1.2 the unit, we must put $s_1 = .9{,}706 \times 1.2$, and $s_2 = .9{,}760 \times 1.2$. Let W be the weight of air due to complete combustion, W_2 that of the nitrogen of the mixed gas, then the total weight will be—

$$(W_1 + W_2 + W) \times 1.2 \text{ atmosphere.}$$

* The blocks of anthracite, or coke, being continually heated by the gas of combustion, have all the advantages of Mr. C. Siemens' regenerating furnace.

The total volume injected in one second will be the sum of the volumes of the air and of the component gases, that is of each component in the blast, and will be equal to the sum of their weight divided by their specific gravities respectively, that is, we must have in one second of blast—

$$\frac{W_1}{s_1} + \frac{W_2}{s_2} + \frac{W}{4} = 35.3,198 \text{ ft.}^3.$$

Now, $W_2 = \frac{W_1}{3}$ (by hypothesis). The oxygen required to burn W_1 is $= \frac{8}{14} \times W_1 = \frac{4}{7} W_1$, and the nitrogen of the air which furnishes this oxygen will be $\frac{77}{23}$ of its weight, so that we have

$$W = \frac{4}{7}\left(1+\frac{77}{23}\right)W_1 = \frac{4}{7} \times \frac{100}{23} \times W_1.$$

Thus finally we obtain

$$\frac{W_1}{s_1} + \frac{W_1}{3\,s_2} + \frac{4}{7} \times \frac{100}{23} \times \frac{W_1}{4} = 35.3,198 \text{ ft.}^3$$

If we put 1.2 for the unit of air we get $s_1 = .9,706 \times 1.2$, and $s_2 = .9,760 \times 1.2$, so that the equation becomes—

$$\frac{W_1}{.9,706} + \frac{W_1}{3 \times 9,760} + \frac{400\,W_1}{7 \times 23} = 35.3,198 \times 1.2 \times 1.2. \quad \text{oz. av. atmo.}$$

Whence we obtain for the value of the weight W_1 sought—

$$W_1 = \frac{31.3,198 \times \overset{\text{oz. av.}}{1.2} \times \overset{\text{atmo.}}{1.2}}{\frac{1}{.9,706} + \frac{1}{3 \times .9,760} + \frac{400}{7 \times 23}}$$

Effecting the numerical calculations indicated, we find

$$W_1 = .260 \times 1.2 \times 1.2 \times 35.3.198 \text{ oz. av.}$$
$$= .82,648,332 \text{ lbs. av. per second of time.}$$

Thus the weight of carbonic oxide gas injected per hour is 2,975.333 lbs. In two hours (which for the present will be assumed as the utmost limit of the operation, in order to compare the results with those of ordinary puddling) the weight injected is 5,950 lbs., or nearly 2 tons 13 cwt. 0 qrs. 14 lbs.

If pure carbonic oxide be employed the quantity blown in and burned in the same time is not quite 4 tons. This may be calculated by neglecting the second term in the denominator of the fraction, which term represents the nitrogen in the compound gas.

It has been shown that we can command, by admixture of the pure carbonic oxide with the cupola gases, 2 tons 3 cwt. (if need be) per ton of iron of the above gas, so that there is an ample supply for all purposes. We are thus able to insure any temperature of combustion from 1,900 deg. C to 2,979 deg. C, which, besides refining and converting the cast iron, may enable us to form valuable alloys with other metals, which alloys have hitherto been thought to be hopeless on the scale of manufacture.

If we employ pure carbonic oxide, which it is probable, as we shall see presently, would be the most economical in time, labor, and fuel, and then convert successfully in the products of combustion the $C O_2$ into $C O$, as above described, we shall find as follows:

	C O per cent. in the gas.	Temperature of combustion. Deg.
1st conversion	51.11	2.355 C.
2d "	41.07	2,075
3d "	37.40	1,976

Pouillet found the point of fusion of "spiegeleisen" to be from 1,050 deg. to 1,100 deg. C., and we see that our lowest temperature much exceeds it. Grey metal, according to his assays, melted at from 1,100 deg.C. to 1,250 deg. C.

The following is a table drawn up up by M. Pouillet:

Points of Fusion.

Of slightly fusible white cast iron.....	1,100 C.
Of slightly fusible grey cast iron.....	1,300
Of slight fusible steel	1,400
Of malleable iron.....	1,600

Plattner makes the point of fusion of malleable iron 2,100 deg. C., and the author has taken this as the greatest heat to which the metal bath need be raised, though he regards M. Pouillet's as the better determination. It is, however, quite clear that the high temperature will insure the reduction of the protoxide of iron by the carbon of the metal, not to mention the other foreign elements.

6. I have calculated the temperature of combustion of the above several kinds of gases without reference to the purpose to which their heat is to be applied; we will now take the practical case of a metal bath containing 10 tons of iron, and we will inquire "to what temperature the carbonic oxide blown in during two hours will raise such a mass of metal?"

We will take, first in order, the gas containing 75 per cent. of carbonic oxide, and 25 per cent. of nitrogen, of which we found

that 5,950 lbs. are injected in two hours. We suppose that the gas and the air have an initial temperature of 500 deg., and the molten iron an initial temperature of 1,400 deg.

M. Scheinz, C. E., of Strasburg has fortunately given a series of determinations of the specific heat of two typical kinds of cast metal for every 100 deg., from 1,150 to 2,000 deg. The mean of these at 2,000 deg. (the least favorable values of the author's method) is 1,914.

The kilogramme is little more than $2\frac{1}{5}$ lbs. English, so that if we take $\frac{5}{11}$ ths of the above weight of 59.50 lbs., we shall have 2,704.54 kilo.=W_1 (above) and $W\frac{1}{3}$=the combined nitrogen is 901.50 kilos. The oxygen for combustion will be $\frac{4}{7}$ W_1 or the CO_2 will be $\frac{11}{7}$ W_1=4,249 kilos. The nitrogen due to this oxygen in the air will be 5,130.42 kilos., the total oxygen will therefore be 6,031.92 kilos. With the above data we find as follows:—

Specific heat of CO_2		
due to 1°.....2,704×$\frac{1}{7}$×.216		917.784
Ditto. N 6,031 92×.244		1,471.788
10,000 kilos. of Fe. 10,181×1,914		1,948 643
Total specific heat for 1°.....		4,338.215
Calories due to		
C O	2,704.54 × 2,400°	6.490,896.000
Ditto. CO_2 917 784×	500°	458,892 000
Ditto. N 1.471.788×	500°	753,894 000
Ditto Fe. 1,948.643×	1,400°	2.728.100 000
Total calories.....		10.371,782 000

If we divide the latter by the former, we obtain as the common temperature of the metal bath, and the products of combustion after two hours operation, 2,398 C.

Now, we do not require so great a heat as this. A temperature a little above the melting point of malleable iron, say 2,150 deg. C. (taking the numbers of Plattner), would be amply sufficient to insure the fluidity of malleable iron or homogeneous iron, and, during the increase of heat up to that point, the reduction of the protoxide of iron in the ores employed. This reduction begins to be sensible at 650 deg. in the blast furnace.

7. We are led by this result to inquire what quantity of carbonic oxide, and what duration of the operation would suffice to give us this temperature of 2,150 deg. C.

In order to arrive at the solution of this question we must take the inverse of the preceding problem, and, assuming as an unknown quantity the quantity of gas required, proceed to determine its value by means of the preceding data and its relation to the temperature supposed.

Let then t be the number of kilos. of the gas required to raise 10,000 kilos. from 1,400° to 2,150°, with a gas of this composition where t represents the carbonic oxide contained in the weight $t + \frac{t}{3}$ of the gas.

These t of C O give $2{,}400\ t$ calories or units of heat. They require of oxygen to burn them $\frac{8t}{14} = \frac{4t}{7}$ forming $\frac{11t}{7}$ of $C\ O_2$. The nitrogen of the gas is $\frac{t}{3}$, that due to the oxygen of the air is $\frac{77}{23} \times \frac{4t}{7} = \frac{44t}{23}$, so that the total nitrogen will be $\frac{t}{3} + \frac{44t}{23}$. For a rise of 1° of temperature the specific heat will be—

Of $\frac{11t}{7}$ kilos.	of C O_2....	$\frac{11t}{7}\times.216$	$=.339\ t.$
Of $\frac{44t}{23}$	ditto N....	$\frac{44t}{23}\times.244$	$=.475\ t.$
Of $\frac{t}{3}$	ditto N	$\frac{t}{3}\times.244$	$=.081\ t.$
Sum.....	.....	.....	$.895\ t.$

10,000 kilos. of metal—$10{,}000 \times .1{,}914 = 1{,}914$, making the total specific heat due to a rise of 1° in the aggregate of products and metal $1{,}914 + .895\ t$. (1.)

For the calories we have:—

From C O.....	$2{,}400\ t$
$\frac{11t}{7}$ CO_2 at 500° / $\frac{44t}{23}$N ditto / $\frac{t}{3}$N ditto	.... $447.500\ t$

From 10,000 kilos. of metal at 1,400°—$10{,}000 \times 1{,}400° \times .1{,}914 = 2{,}679{,}600$.

Total calories—$2{,}847.500\ t + 2{,}679{,}600$. (2.)

If we divide (2) by (1) we have the temperature $t°$ of the bath and products of combustion:—

$$t° = \frac{2{,}679{,}600 + 2.847.500\ t}{1{,}914 + .895\ t} = 2{,}150°.$$

From this equation we find $t = 1{,}554$ kilos., and the total gas is $t \times \frac{t}{3} = 2{,}072$ kilos. The time required for the injection of this 1,554 kilos. is 2 hours $\times \frac{1554}{2072} = 1$ hour 17 min. 28 secs.

8. Let us lastly take the case of pure carbonic oxide. The weight injected in two hours will be found to be 6,797 lbs. avoirdupois, or somewhat above three tons. This is equal to about 3,090 kilos. in two hours. Let us, as before, suppose that we require t kilos. to raise 10,000 kilos. of metal from 1,400° to 2,150°, then the time required for this will be $\frac{2t}{3090}$ hours. The statement of the analysis will be as follows:—t kilos. C O give out 2,400 t calories or units of heat, requiring $\frac{8t}{14} = \frac{4t}{7}$ kilos. of oxygen to burn it, and forming $\frac{11t}{7}$ kilos. of CO_2. As the C O is at 500°, and the air also, the specific heat of $\frac{11t}{7}$ kilos. of C O_2 will be $\frac{11t}{7} \times 500 \times .2.6$ or $\frac{11t}{7} \times 1{,}000 \times 108 = 169.714\ t$. The $\frac{4t}{7}$ kilos. of O import $\frac{77}{23} \times \frac{4t}{7}$ of nitrogen $= \frac{44t}{23}$, which at 500° gives a specific heat of $\frac{44}{23} \times 500 \times .244\ t = 44 \times 1{,}000 \times .122\ t = 233.400\ t$. At 1,400°, 10,000 kilos. of cast-iron have $1{,}400° \times 10{,}000 \times .1.914$ of specific heat = 2,679,600. We have, therefore, of calories—

Due to C O.....	2.400 t.
" C O_2 at 500°.....	169.714 t.
" N at 500°.....	333.400 t.
10,000 kilos. of Fe at 1,400°.....	2,679,600 t.
Total calories = 2,863.114 t +	2,679,600

In rising by 1° we have of specific heat in—

$\frac{11}{7}$ kilos of C O_2.....	$\frac{11}{7} \times .216$	.339
$\frac{44}{23}$ " " N	$\frac{44}{23} \times .244$	.475
		.814

$\therefore$ t kilos. will have .814 t; 10,000 kilos. of iron in rising 1° take $10{,}000 \times 1{,}914 = 1{,}914$ of specific heat.

If, then, we divide the total calories above by $.814\ t \times 1{,}914$, we shall, as in the last case, have the common temperature of the products of combustion and of the iron, which we assume to be 2,150°. This gives us the equation in t:—

$$\frac{2679\ 600 + 2863\ 114\ t.}{814\ t. + 1{,}914} = 2.150°.$$

whence it is found to be 1,290 kilos, nearly. The time required to inject this quantity will be $\frac{2}{3090}$ hours $\times$ 1,290, or a little more than 50 minutes.

At this point it is necessary to remark that the extreme heat of 2,150 deg. will be required only towards the end of the operation, when the carbon of the metal is nearly all taken up, and the metal is the least fusible. A temperature of less than 1,400 deg. will suffice to oxidize the silicium, the phosphorus, and the sulphur, and to reduce the protoxide of iron by the action of the carbon.

We shall revert to the results obtained in the last two cases when we come to calculate the cost in gas per ton of produce. Assuming that the above analysis and description of the process and of its attendant phenomena have established the soundness of the physical and chemical part of the process, it remains to consider it in the economical and commercial point of view. A finery hearth of 10 ft. by 5 area, with a depth of metal equal to the average depth of a charge in a Bessemer converter, would allow of the treatment of 10 tons of metal at a heat. Two hours were assumed as the possible duration of this treatment, but it has just been seen that, as regards the heat, from less than one hour to one hour 20 min. is quite sufficient. In practice, we should commence with a degree of heat little, if any, above the heat at which the charge was run out from the cupola into the finery, and raise it by degrees, as should become necessary, to the full development of the reactions employed.

Two methods would have been selected for producing the carbonic oxide gas required, and a third is under consideration. The first is the calcination of broken limestone in close retorts by means of waste gases, and the conversion of the carbonic acid gas evolved into carbonic oxide in connected retorts containing anthracite coal or pure clean coke. When there are blast-furnaces, calcined lime is obviously beneficial as well as economical, were it only that it would prevent the cooling of the furnace by its change of volume in becoming changed into carbonic oxide, and by its own change from the solid in the stone to the aeriform state which must take place somewhere with the absorption of latent heat. For the rest, it can be more cheaply calcined in retorts with the waste gases than in the ordinary limekiln.

A second mode is the employment of the gas produced by passing highly heated

steam over incandescent coke or anthracite coal. The hydrogen contained in such gas, however, limits the proportion in which it may be safely mixed with cupola or other gases, while the vapor of water formed by its combination with oxygen, or combustion, with its great specific heat, would reduce the temperature.

Estimate of the probable cost of carbonic oxide produced by converting the carbonic acid gas of limestone calcined in retorts heated with waste gases, and passed through adjoining retorts, containing anthracite coal or coke.

The limestone contains — lime, 54.10; carbonic acid, 42.20; and it requires about two hours for its complete calcination. The cost of the limestone, labor, etc., are paid by the lime produced. One ton of limestone yields $\frac{42.2}{100} \times 20$ cwt., or 8.44 cwt. of C O_2. To convert this 8.44 cwt. of C O_2 into C O, we require $\frac{6}{22} \times 8.44 = 2.30$ cwt. of carbon, forming 10.70 cwt. of C O. To yield this 2.30 cwt. of carbon, we require of anthracite coal (91.44 per cent. of carbon) 2.62 cwt., say 275 cwt. Thus our amount stands—

	s.	d.
8.44 cwt. of C O_2	0	0
2.75 cwt. of anthracite at 12s. per ton	1	8
Two hours' labor, 1 man to 4 retorts	0	10
Wear and general expenses	0	2
Cost of 10.74 cwt.	2	8

Or about 5s. per ton.

In forming this gas of 75 per cent. CO. and 25 per cent. N., we employ 58.745 cwt. of pure C O and 22.362 cwt. of cupola gas. The latter gas contains only 34.42 per cent. of C O, or 7.67 cwt. of pure C O. The total C O due to both sources will be 66.41 cwts. of which the pure C O is 58.74. We must, therefore, take $\frac{58.74}{66.41}$ of the 1,554 kilos. of C O, or 3,419 lbs. av., as that part which costs 5s. per ton. This amounts to 3,024 lbs., which, at 5s. per 2,240 lbs., amounts to 6s. 9¼ d., being 81.25d.

If, now, we divide by 10 the number of tons treated at a heat, we find the cost per ton of iron balls to be as nearly as possible 8d. per ton. The cost of melting is 3½ cwt. at 12s. per 20 cwt., or not quite 2s. 2d., so that the total cost of fuel is 2s. 10d. per ton of balls or blooms. It is premature to offer an estimate of the cost of labor, but allowing liberally for one engineer, one sub-engineer, one laborer, and two head finers with two aids, we find the total cost per heat of 10 tons to be 2s. 6d., or 3d. per ton of metal ready for balling. To this have to be added the cost of the iron ores and that of caustic soda, which latter, for the worst metal, is now 7s.* per ton; the ores costing about 9s. 6d † This is a total of 19s. 7d. per ton of metal balls. Against this we have to set the gain in produce of 20 per cent., or from 4 to 5 cwt. of iron (the produce of the iron ore employed to oxidize the impurities and the carbon of the metal), which, at only 6s. per cwt., is from 24s. to 30s. In puddling we have coal 15s.; labor, per ton, 12s.; fettling, at least 3s., with other expenses, amounting in all to above 30s.; so that, even with the present high prices, there is a saving of not less than 10s. a ton, independent of any gain in produce, or any question of quality and price. Moreover, this is the cost of common impure metal, which cannot be made to yield good iron at all in the puddling furnace. Good metal requires very little soda, and only iron ore enough to discharge the carbon (about 3s. 6d. cwt.) at some 5s. per ton, the gain in produce being 5½ cwt. per 20 of metal. It must be distinctly understood, therefore, that all that part of the above cost per ton which exceeds 2s. 10d. for labor and gas, and 5s. for iron ore to take up the carbon (a total of 7s. 10d.), is laid out solely for the purpose of making good bar iron out of bad and intractable metal without loss in yield.

The cost per ton of carbonic oxide prepared by the third method under the author's consideration is 6s. 2d. Ths cost of its consumption (2,838 lbs.) per ton of produce is about 9½d., and adding to this 2s. 2d. for the melting, makes the total cost of fuel per ton of iron about 3s. To this the preceding remarks equally apply. It might seem, at first, that this cost of preparing carbonic oxide in retorts is too low. It is necessary, therefore, to state that all the materials for making the gas will be charged into the retorts by machinery of very simple construction, which dispenses with manual labor.

The materials, being prepared for the retorts, descend through a hopper into a long

* Exceptionally high; it was only 3s. 6d. in 1870.
† At present high prices.

gutter, furnished with apertures above the retorts, which apertures may be closed at will. In this gutter an archimedean screw, shaped like a flat-wormed corkscrew, revolves and carries forward to the apertures the materials, which drop through into the retorts. The retorts are so constructed as to admit of being closed by a mechanical movement, and of being discharged similarly. With such an apparatus two men may attend to a hundred retorts.

We may illustrate as follows the gain in the yield of 20 cwt. of metal:—

1. The usual loss of 8 to 10 per 100 in puddling (say 8) is 1.6 cwt., which is saved. The metal containing 3 per cent. of carbon, this requires (it being on 20 cwt. 6 cwt.) $\frac{3}{5} \times \frac{8}{6}$ cwt. of oxygen to form carbonic oxide, or $\frac{4}{5}$ cwt. The protoxide contains in nine parts, two of oxygen and seven of iron. If then x be the weight of it required, we must have $\frac{2x}{9} = \frac{4}{5}$, or $x = 3.6$ cwt., which, at 30s. a ton, is 5s. $4\frac{3}{4}$d. The iron reduced from this protoxide will be $\frac{7}{9} \times 3.6$, or 2.8 cwt. This added to 1.6 makes a total gain of 4 4 cwt.

Only the richest and purest ores are to be used, but still a small allowance is to be made for earthy matter; this, at 10 per cent., would be 36 cwt. In fact, it would rarely exceed five per cent., so that if we allow 4 cwt. it would be ample, and this leaves a clear gain of 4 cwt.

If we suppose in the ores which contain much silicium, phosphorus, etc., that these elements, upon their oxidation, reduce the iron ore, the increase of yield would be larger. The increase above estimated cannot be unreasonably large, for Mr. Danks claims to have increased the yield by 15 per cent., which is 3 cwt. at least. There cannot, it is submitted, be much doubt that at so great a heat a sensible quantity of sodium would be reduced and thrown into the metal. This would, as Baron Gruner and Professor Miller have suggested, have a powerful effect in purifying the iron in the re-heating operation.

Much, however, has yet to be learned as to the behavior of the iron, of its impurities, and of the reactions to which it would be submitted at these high temperatures; but there is good ground for hope. Mr. Bessemer is said to have tried the nitrate of soda with his air blast; but Baron Gruner states that in the presence of fire-brick this is quite illusory as regards the expulsion of phosphorus, in fact a pure waste of the reagent.

It has been stated above that the iron may be "balled" by machinery when it is "coming to nature." This observation, however, had reference much more to the possible preference of the iron-master than to any supposed necessity for the operation. The fact is that the iron at so high a temperature, though malleable, remains in fusion, so that it may be cast into blooms ready for the hammer and the rolls, when sufficiently set by diminution of the temperature. This process, being nearly mechanical, would be far less costly than that of balling, while the iron would be free from scoriæ and "cleaner" (in the phrase of the trade). In truth, the whole process is chemical and mechanical from beginning to end.

It is hardly necessary to add that the crystalline structure of the metal will be broken up by the hammer and the rolls and replaced by the fibrous.

Note I.—Since the above was written the author has found two ores of iron admirably suited to this process—the "Marbella" magnetic ore, and the "Iserine," or Titaniferous magnetic ore, in the state of a fine sand, both of which may be obtained to almost any amount at about 30s. per ton. The "Marbella" would be greatly improved if ground up with one-fourth of its weight in "Ilmenite," in which the oxide of Titanium attains to 40 per cent.

Note II.—If it be the object to obtain very superior iron or steel, for special purposes, from cast iron free from impurities, nitrate of soda may be employed. This being injected with the blast (which in such case need not be heated) in small quantities at a time would have all the effect of the Heaton converter, without its waste of the nitre. The cost per ton of iron would be trifling, such metal being practically free from sulphur and phosphorus.

Discovery of Coal near Bagdad.—A coal mine has been discovered in the Bagdad district, between Yezireh and Zeto. According to the report of M. Mongel, engineer to the Viceroyalty, the formation extends over a length of more then seven kilometres, with a breadth of from 150 to 200 metres. Eighty-four tons were got out during the first three weeks of working.

HEAVY GOODS LOCOMOTIVES.

From "Engineering."

The extremely heavy character of the goods traffic to be carried on some of the leading Continental railways, and particularly on some of the mountain lines more recently constructed, has called into existence several types of powerful locomotives differing materially from any in use in this country. The Vienna Exhibition contained many examples of such types, and as a large proportion of these have already been illustrated and described in this journal, our readers must be familiar with the chief modes by which the Continental locomotive engineers have endeavored to solve the problem before them, namely, how best to produce locomotives of exceptionally great tractive power. Our object in the present article is to speak of some of these plans, and to compare them with other modes of attaining the same end.

In the majority of cases the locomotives built for exceptionally heavy work on the Continent are eight wheeled, all wheels being coupled, and all axles being under the barrel of the boiler. The cylinders are outside, and in a large number of instances the engines are built upon Hall's system, and have outside frames and outside cranks. The wheel base is kept as short as possible, and flexibility is given by allowing lateral play to the trailing—or in some cases both leading and trailing—axles. Such, in broad terms, are the leading characteristics of the exceptionally heavy goods engines now made on the Continent, and it is undeniable that such engines do a large amount of work at slow speeds in a fairly satisfactory way. Notwithstanding this, however, it is, we think, equally undeniable that they possess many grave defects which may be avoided by adopting another system of construction.

In the first place the necessity which exists for maintaining a short wheel base has led to the practice of putting all the axles under the barrel of the boiler, the result being an excessive length of boiler barrels and of tubes—tubes 15 ft. and 15 ft. 6 in. long being common, whilst, in some cases, the length reaches 16 ft. 6 in. To make the engines ride more easily, also, compensating beams are generally being introduced between the driving and trailing springs, and not unfrequently between the springs of the leading and second wheels also, and these compensating beams, although undoubtedly useful for reducing shocks, tend in some cases to reduce the control of the longitudinal oscillations or pitching motion to which the excessive overhang of the engines gives rise. Considering that the normal load on a pair of wheels in one of these heavy engines is generally between 12 and 13 tons, it is evident that the oscillations and augmentations of this load, due to insufficiently controlled pitching motion, must have a most serious effect upon the road, and most materially increase the cost of maintenance of the latter.

The true remedy for this state of things is, as we have stated on former occasions, the adoption of the double-bogie system. Once let that system be adopted, and we get rid of all difficulties such as those to which we have just alluded. We can lengthen the wheel base of the engine to any desired extent, so as to obtain longitudinal steadiness, while, at the same time, we retain the utmost facility for traversing sharp curves, and especially we get rid of those variations of load per wheel due to pitching, which, in engines with great overhang, play such havoc with the permanent way. In a double-bogie engine the weight of all parts above the bogie is transmitted to the bogie pins, and is distributed over the wheels of the bogies in the proportions determined by the positions of those pins, the distribution thus effected being practically constant under all circumstances, and being only modified to an immaterial extent by the motion of the reciprocating parts of the working gear. The advantages of this state of affairs are even greater than may at first appear. If the construction of an engine is such that the normal load per axle is liable to be sometimes increased by the pitching action to the extent of 30 or 40 per cent., then in fixing the normal load this circumstance must be allowed for, and the load made less than it might be if its constancy could be insured. The double-bogie system, as we have seen, gives this constancy, and hence it follows that in an engine constructed on that system a greater load may be carried upon each pair of wheels than would be safe under other circumstances. On the other hand, also, the

double-bogie system gives every facility for decreasing the load per wheel if desired. Practically, it is found undesirable to couple more than four pairs of wheels; but if we divide our power between two groups, each with its own pair of cylinders, we at once double our power of distributing the load, and can, if necessary, divide that load between sixteen wheels instead of eight without incurring difficulties. Taking into account the constancy of the distribution of the load already alluded to, however, we are inclined to believe that it will be on but very rare occasions necessary to resort to eight-coupled bogies, a maximum of six wheels per bogie, or twelve in all, being, we think, all that is likely to be required even for mountain locomotives, at all events for many years to come.

Another advantage of the double-bogie system attendant upon the features which we have jnst pointed out, is that it enables us to produce tank engines for the very heaviest classes of work, and capable of carrying large supplies of water and fuel. The eight-coupled type of engine so much favored on the Continent is quite unadapted for transformation into a tank engine, as the load per wheel in those engines is already as great as it is safe to carry under such conditions, and hence they are made generally with a light class of tender, the weight of which, however, is always, and necessarily so, greater than that of the tanks and coal bunkers required to make the double-bogie engine carry its own fuel and water. As every ton saved in the weight of an engine—or of an engine and tender combined, if a tender is used—without decreasing its efficiency, means so much added to the useful load it is capable of hauling, the importance of this is evident.

It has been urged in some quarters that it is a mistake to carry the fuel and water on engines intended for heavy work on inclines, as the weight available for adhesion becomes reduced as the incline is mounted; the fallacy of such an argument is almost self-evident; but as the objection has been seriously advanced, it may be worth while to say a few words respecting it. It will, we think, be conceded that for very low speeds, such as are resorted to on heavy gradients, engines may be constructed in which the hauling power is limited only by the adhesion available. In other words, the boiler and cylinder power may at these low speeds always be in excess of the adhesion. This being so, it is desirable to turn to account, for increasing the adhesion, the weights of all necessary parts of the engine, amongst which the tanks and fuel bunkers must evidently be counted. If these parts be mounted on separate wheels, and thus formed into a tender, they simply increase the load to be drawn, and reduce by so much the weight of train which the engine is capable of hauling. If, on the other hand, they are carried on the engine itself, they increase its hauling power to the extent due to their own weight, and this whether they are full or empty.

There is another point in which the double-bogie system offers an important advantage, and that is, in the facility it affords for the construction of very powerful boilers carrying high pressures of steam. An examination of the large goods locomotives now being constructed on the Continent will show that the limits of steam-generating power afforded by the ordinary locomotive boiler have practically been reached. Already there are running boilers 5 ft. in diameter—a diameter which is nearly as great as can well be accommodated, while it is one which necessitates the use of very thick plates, or else a reduction of the pressure below that with which the best results are being obtained in this country. It is quite true that 5-ft. boilers may be made to stand far higher pressures than those at which they are now worked, while, of course, if necessary, $\frac{7}{8}$ in. or 1 in. plates could be employed in their construction, just as they are in modern marine boilers. But in the case of locomotive boilers the use of such plates would lead to many difficulties, and we think few locomotive superintendents would care to adopt them. If, now, the double-bogie system be carried out in its integrity, as is done by Mr. Fairlie, the engines being built with a double boiler and central firebox, we at once get rid of all difficulties about boiler power. It is evident, in fact, that this system gives us the means of producing boilers twice as powerful as any ordinary boilers now in use, without increasing the thickness of plates; or, on the other hand, if the present power be retained, it enables us to reduce the diameter of boiler barrels, and to employ plates of a more manageable thickness. It also, as we have frequently pointed out, gives us the advantage of a constant depth of water over the firebox crown, whether the engine is on a level or on gradient,

whilst it likewise enables us to increase the fire-grate area to any desirable extent without producing the evils due to overhang.

We have already alluded to the excessive length of tubes employed on many Continental goods engines, and we have pointed out that this is due to the packing of all the wheels under the barrel of the boiler. We have known it urged that this great length of tube is necessitated by the nature of the fuel consumed on many Continental lines, the long tubes being required to obtain a reasonably good evaporative duty from the inferior class of coal available. In other words, it has been stated that the length of the tubes is not a result of the position of the axles, but that the position of the axles has resulted from the necessity for long tubes. This argument is, however, directly negatived by the practice of the engineers by whom these long-tubed engines are built, for on the very lines on which eight-coupled engines with tubes 15 ft. 6 in. to over 16 ft. long are at work, we find also in use six coupled and passenger engines with tubes of the same diameter, but 2 ft. to 3 ft. shorter. As all these engines are using the same fuel, and as longer tubes could certainly be used in the two latter classes of engines, if it was specially desirable, the natural deduction is that the tubes are shortened when circumstances permit of this being done. With the double boiler the tubes can of course be kept with the ordinary proportions of length to diameter. The subject of locomotive boiler proportions for different classes of work and varieties of fuel is, however, one on which much could be said, and as we hope shortly to discuss it in detail, we shall not enter further into it here.

We have necessarily, in the present article, repeated many arguments, which we have advanced on former occasions, and we have done this because we see on all hands an increase in the class of railways on which, of all others, the double-bogie system can be employed with advantageous results. Everywhere there is a tendency to build lines of moderate first cost; this desire to economize on the original outlay leading to the adoption of steeper gradients, sharper curves, and a narrower gauge, besides, in many cases, a lighter type of permanent way. By the adoption of Fairlie engines such lines can be made to accommodate an amount of traffic which is out of the question so long as ordinary locomotives are used, unless, indeed, the latter be employed to a great disadvantage. On mountain lines of more costly construction, or on other railways having to accommodate a very heavy goods traffic, the adoption of the double-bogie system would not only enable an increase to be made in the loads drawn, but would effect a most material reduction in the cost of permanent way maintenance, a matter which is but too often neglected by those having to provide locomotive power. As we have recently had occasion to state, the Fairlie system is no longer an experiment, but an established fact, and it behooves all in charge of such lines as we have mentioned, to learn for themselves the lessons which it teaches on the railways where it is in use.

CORROSIVE EFFECTS OF IMPURE WATER UPON SURFACE-CONDENSER TUBES.

By J. A. HENDERSON, M. E.

Written for Van Nostrand's Magazine.

Having been recently called upon to make an examination into the cause of a corrosion taking place in the tubes of the surface-condenser in use at the "Metropolitan Flour Mills" of Messrs. Hecker & Bro., the matter was taken in hand, and a report written out, of which the present article is essentially an embodiment.

Prior to giving the results of the examination, a short description of the condenser and its circumstances becomes necessary. It is one of Lighthall's manufacture, being of a long and narrow rectangular form, provided with 1,800 $\frac{3}{4}$ in. (external diam.) brass tubes, put in horizontally, and arranged for the water supplied for effecting condensation, to pass inside and the steam outside of the tubes. This condenser is now used solely to obtain a constant supply of distilled water, and so to save a large water rent as well as to prevent the necessity of frequently cleaning the boilers; no air pump is at-

tached and no vacuum carried. The condensation water passing through the tubes, is pumped from the innermost end of one of the East River docks, from which the mills are distant only a few hundred feet, and is rendered visibly impure by the discharge of a sewer having its outlet in this same dock, the impurities being confined not only by there being but slight draught of water, but also by the tidal currents being largely cut off by an adjoining stone division wall, extending out 50 ft. or more from the mouth of the sewer.

The tubes first began to be corroded completely through, some 18 months after the condenser was put in, and have ever since steadily continued to give out, often at the rate of several per week. The leaks become apparent by the presence of quantities of salt in the boilers, and the individual tubes to which they belong have to be renewed, after having been detected by filling the external steam spaces with water, and observing any flow from their ends in the tube-plates, thus involving delay as well as expense and trouble.

In taking up the problem of investigating the definite cause of this corrosion, the first point to be noticed was the actual nature of the perforations in the tubes. The completed holes appear from the outside nearly round in form, and of all sizes up to ¼ in. or more in diameter; they seldom occur in greater numbers than 3 or 4 in any one tube, and, as afterwards stated, seem most apt to be situated along the same straight line at the lowest part of its surface.

Several pieces of the perforated tubing were brought away and sawn or split open lengthwise, to examine the internal surface and compare it with the outer. The perforations were found invariably to begin from the inner surface, as pits of partially corroded metal of all depths existed there, while the outer surface remained intact, except in the immediate neighborhood of completed perforations where a drip from within had begun. These internal pits, extending only partway through, although not so apparent at first sight, were readily detected by scraping with a knife, and were very numerous. The action of the water seems, however, to have been by no means confined to them alone, because the whole of the internal surface exhibited traces of similar corrosion, as was indicated not only by its being soft and brittle compared with the outer metal, but by its being perceptibly thinned in many places. In proof of internal corrosion, it was further noticed that the pits, as well as completed holes, if not too much enlarged by leakage, were always largest near the inner surface, where the action first began.

Because of the corrosion thus taking place on those surfaces of the tubes directly in contact with the water used in effecting condensation, and in a much more rapid manner than is the case with the tubes of ordinary marine surface-condensers, having substantially the same construction as the one in these mills, it follows that the trouble under consideration must be due to one or the other of two causes, viz., either the presence of some agent or corrosive substance in the condensing water which is foreign to pure salt water, or the presence of impurities or flaws in the metal of the tubes, having essentially the forms of the pits, perforation, etc., just considered, and more readily attacked by ordinary salt water than the brass commonly used for marine condenser-tubes.

There are no other conceivable causes than those two just mentioned, to account for this example of rapid corrosion. As for galvanic action, aside from the consideration of the nature of the water, the conditions are precisely the same as in many other surface-condensers in use, and in fact such action (which in all probability exists whenever any chemical change is taking place) would be in favor of preserving the tubes at the expense of the cast-iron walls of the condenser, and might further be made use of in preserving both tubes and walls by introducing or suspending in the path of the water, a sufficient quantity of some finely divided metal capable of being acted upon more readily than cast-iron or brass, such for example as thin plates of wrought-iron or zinc. This method of procedure would, however, not be likely to be of much avail in this case of a surface condenser, owing to the mass of water passed through the tubes, and also perhaps to the latter being put in with wooden ferrules and so partially insulated from the iron.

In taking up the last of the two causes previously mentioned as capable of producing this corrosion, it must be stated that the tubes are of a standard New England manufacture, and are furnished to a large portion of the surface condensers used in this country, where they are known to last

for a term of years, several times as long as the period of only 18 months in the present case. This in itself directly points out that something other than flaws or impurities in the brass must be the cause of the trouble, and this last statement is verified by the fact that as the tubes are seamless and have to be drawn, imperfections could never exist of forms like the pits and holes here existing, nor would they in any probability be wholly confined to the interior of the tubes. In final proof of the metallic composition of the tubes being what it should be, the results of a qualitative analysis of the corroded brass indicated the presence of no other metals in appreciable quantities besides the copper and zinc, than very faint traces of iron and tin, the former probably being deposited as oxide from the water, and the latter constituting the remnants of the internal tinning.

Independently, therefore, of any further examination, it is a priori to be concluded with almost certainty that the destructive agent is contained in the condensation water, and that it is something not met with in the relatively pure salt water used in the supply for surface condensers of vessels at sea.

The conclusion just given was further confirmed by the results of chemical examinations of the deposit of scale and corroded metal scraped from within the tubes, and of several samples of the condensation water.

The analysis of the scrapings from the tubes was made with the more special object of detecting the presence of those acids or other non-metallic elements, in combination with the brass, and derived from the water, only of course those whose compounds with copper or zinc are practically insoluble being expected to occur in any quantity. The following substances were found present, besides the metals in the brass, and some mud containing a little lime: sulphuretted hydrogen (in small quantity, existing as sulphide), sulphuric, acetic (only traces) and carbonic acids, and ammonia, all of which were combined either with the copper or zinc; except the sulphuric acid, which was due to a slight deposit of sulphate of calcium (boiler scale); and were to be anticipated as existing in some form of combination in the condensation water. As, besides, this combined and inert (as far as corrosion is concerned) sulphuric acid (in solution as well as in carbonate of calcium) is the only one of all these that exists in pure sea water, the sulphuretted hydrogen, ammonia, and acetic acid must have constituted a portion if not the whole of the substances whose presence as impurities in the water, is the cause of the corrosion that we are considering.

The samples of condensation water analyzed were taken from the ends of the condenser just outside of the tube plates, and contained a good deal of a heavy organic sediment, that in time collects there. There was found, by the analysis, in addition to a somewhat reduced quantity of the dissolved constituents of common salt water, and the black, insoluble, and but partially decomposed organic matter, sulphuretted hydrogen, mainly combined with this sediment; ammonia, in sufficient excess to retain an alkaline reaction over any acids present; free carbonic acid, in greater proportion than in pure salt water, together with traces of acetic, nitric, and phosphoric acids, existing as acetates, nitrates, etc., the whole of which are to be traced to the decomposing matter discharged by the sewer into the dock from which the water is derived.

All of these substances having already been found in combination with the brass of the tubes, with the exception of the salts of nitric and phosphoric acids, whose action on the copper and zinc, if taking place at all, would produce soluble compounds that would be washed away, there is left no doubt of the direct cause of the corrosion. It may be that other substances than those found, exist in the water, and help to produce corrosion, but they were not appreciable in quantity, and it is in fact likely that only the sulphuretted hydrogen, or the ammonia with the assistance of the air and carbonic acid in solution, really effected the result.

These conclusions were further corroborated by making up a somewhat dilute and alkaline solution of sulphuretted hydrogen and ammonia, together with relatively small amounts of salts of the other acids found in the analysis, so as to resemble the impure water in composition, but still be of a much stronger nature, and then observing its action upon slips of clean brass. By this solution the slips were tarnished in a few hours, with a black coating of the sulphide of copper and formation of the blue ammoniacal solution of the oxide, the zinc appearing as flakes of the white sulphide. When immersed in some of the impure water from the condenser, the surfaces of

similar similar slips were acted on in much the same manner, and especially by the sediment, but it took several days to bring about the result, while, when in the purest salt water to be had in this neighborhood, the action was very much less in the same time.

Although recorded facts concerning the effects of foul dock water upon brass were not to be found, it can be stated as well known, that upon unprotected iron (specially wrought-iron), the action is very injurious, the sulphide of the metal being formed with rapidity, through the presence of the sulphuretted hydrogen. When there is an actual contact with masses of undissolved organic matter, as is the case with the nails, bolts, and other scraps of iron buried in the mud near city docks, the change takes place so rapidly that in a short time they become completely converted into the sulphide, and also retain their original shapes. As this solid organic sediment is known to have the same corrosive action upon lead, notwitstanding the great resistance of this metal to being attacked by many of our most powerful chemical agents, it is probable that the same would be true for the constituents of brass, and that the heavy sediment which appears in the condenser has a good deal to do with increasing the corrosion. As before stated, this contained a good deal more sulphuretted hydrogen than the water itself, and its observed action on the slips of brass was somewhat greater. It was also noticed that the corrosion in the metal mostly occurs on the same side of any one tube, which side is thought to be the bottom one, from the facts that the deposit of sediment and scale was the thickest there, and that the external corrosion from internal leakage was always confined to the immediate vicinity of the holes, thus showing any drip to have fallen directly downwards. This is a further proof of the direct corrosive influence of the sediment. Still another way in which it may indirectly increase the corrosion is by clogging or partially filling up the tubes, thus obstructing the flow of water, allowing the temperature to approach that of the steam, and so aiding by heat the chemical actions taking place in the corrosion. Both of these statements receive further evidence from another fact not hitherto mentioned, that the majority of the faulty tubes were taken from the lower half of the condenser, where the supplied water first enters, and where the most sediment would be apt to be caught or settle out.

Finally, regarding the remedy for the corrosion, having concluded the whole trouble to lie in the dissolved impurities and sediment contained in the condensation water and directly derived from the sewage discharged adjacent to the supply-pipe, the most obvious remedy is one that had already been proposed by Mr. Reaney, the Superintendent of the Mills, viz., to obtain a better quality of water by running out the pipe sufficiently far to clear the stone wall partitioning off the inner end of the dock, and so to catch the fresh tide water. At this point the draught of water is several times greater, being as much as 25 ft. at low tide, a circumstance that should give an opportunity for obtaining water comparatively free from any solid matter, and especially the heavy sediment such as was examined a little above the centre of this draught at low water would be the place at which to locate the nozzle of the supply pipe, as there would still be about 15 ft. to clear sediment, with ample depth from the surface both to clear floating debris and to get cold water.

Even after running out the supply pipe, it is not to be expected that the trouble will immediately and entirely cease unless the whole of the tubes be renewed at the time of making the change, because otherwise a majority of the old tubes, being already corroded nearly through, would give out in a comparatively short space of time, notwithstanding the slower action of the purer tide water.

It may be here mentioned that were it impracticable to reach a supply of water freed from the corrosive sediment appearing to be the more direct cause of trouble, the steam and water might advantageously be made to change places in the condenser, so that the sediment, having to be deposited on the outside of the tubes, would have no chance to obstruct the flow of water, or to collect on the brass.

To make sure of the quality of the water at the proposed locality for the supply pipe, some specimens were subsequently bottled and analyzed for the detection of those injurious constituents found in the previous analyses.

There was present but very little suspended organic matter, which was of quite a different composition from the heavy,

black, and sulphurous sediment taken from the condenser, being of a lighter color, much more flocculent, and but little decomposed, as was attested by its containing no appreciable amounts of either su'phuretted hydrogen or ammonia. Neither of these substances was detectable in the filtered water, and it seems in fact probable, according to what has been already noticed, that they never do occur in any quantity except in the immediate neighborhood of solid organic matter while undergoing decomposition. Free carbonic acid existed in considerably smaller proportions than in the water previously examined, the amount being no more than might be expected to be held in solution by common sea water. The salts of phosphoric, nitric, and acetic acids, were still present, but in such minute proportions that although the water was evaporated down to about $\frac{1}{20}$ of its original volume, and the salts are non-volatile while in solution at the boiling point, the tests yielded unsatisfactory results. The testing for traces of impurities in sea water is rendered very difficult and uncertain, owing to the presence of relatively immense quantities of common salt, and the other normal saline constituents, such as chloride of magnesium, sulphate of calcium, etc.

The conclusions previously arrived at need in no way be altered by the results of this last examination, when it is considered that those agents most destructive to the brass of the tubes, the heavy decomposing sediment with its sulphuretted hydrogen and ammonia, were here found completely absent, while at the same time all the other substances likely to have any corrosive effect (over and above those occurring in pure salt water) were in much reduced proportions compared with the water previously analyzed, from the ends of the condenser.

Since the results of the above examination were reported, the general conclusions hitherto arrived at and stated in this article have been acted upon, and the work of renewing the tubes of the condenser and of running out the end of the supply pipe is now being carried out.

This case of corrosion at the Metropolitan Mills shows the necessity of observing the nature of the water to be supplied to surface condensers when located in cities where there is a liability of its contamination with sewerage, and is communicated for publication in the hope that its results may prove to be of practical value to mill owners, or others, either now using or proposing to use surface condensation.

NAVAL LABORATORY,
NEW YORK, *Dec.* 4, 1873.

PNEUMATIC TUBES.

From "Engineering."

In consequence of the removal of the Telegraph Department of the General Post Office in London, an important extension of the system of pneumatic tubes was rendered necessary.

To insure economy and efficiency the subject was referred to Mr. R. Sabine, who, as is well known, has given a considerable amount of attention to this subject both here and at Berlin, and than whom perhaps no safer authority upon such a matter could have been consulted. The subject was most carefully gone into by Mr. Sabine, and as the use of pneumatic tubes is yet in its infancy, and may probably meet with increased favor as the facilities which they afford become better known, we purpose giving our readers the benefit of those calculations, which Mr. Sabine has kindly placed at our disposal for that purpose.

The first questions to be considered in connection with this subject are three, viz., 1. The diameters of the tubes to be employed; 2. The pressures best suited for working them; and 3. The engine power.

With regard to the first question, as to the diameter of the tubes, this must, in great measure, in the first instance, be dependent upon the capacity of the carriers for receiving messages. It has, however, been ascertained that a 2¼ in. tube—the minimum diameter which it is proposed should in any case be employed—affords a sufficient carrier capacity for a much greater amount of traffic than the tubes, required for the purposes of the Post Office, are likely to be called upon to perform for some years to come. The question then simply resolves itself into one as to what is the

most economical diameter of tube to employ, and of drawing a balance between the advantage of increased speed obtained, with the same effective pressure in a larger, and that of the less engine power necessary for working a smaller tube; or, when the same speed is obtained in two tubes of different diameters, with different pressures, the question resolves itself into one of the respective utilized engine powers.

Taking then 2¼ and 3 in. lead tubes of the lengths of 1,000, 2,000, and 3,000 yards respectively, and a constant pressure of 10 lbs., carriers would be transmitted through them in the times and with the utilized engine powers shown in the following Table

Length in yards.	2¼-in Lead Tubes.		HP.	Length in yards.	3-in. Lead Tubes.		HP.
	Times of Transit.	Volume of Compressed Air per Minute.			Times of Transit.	Volume of Compressed Air per Minute.	
	min. sec.	cubic ft.			min. sec.	cubic ft.	
1000	0 58	85 3	4.4	1000	0 50	175.2	9.1
2000	2 44	60.4	3.1	2000	2 23	123.9	6.4
3000	5 3	49.3	2.6	3000	4 22	101.2	5.2
And with a pressure of 5 lb. with the same lengths and tubes:							
1000	1 21	61.0	1.5	1000	1 10	119.6	2.9
2000	3 50	43.2	1 0	2000	3 19	88.5	2.1
3000	7 3	35.2	0.8	3000	6 6	72.3	1 7

From these Tables it is at once apparent that with equal lengths and equal pressures, the speed obtained in a 3 in. tube is only 16 per cent. higher than that in a 2¼ in., whilst an engine power more than double is expended on it. Obviously, therefore, any increase of diameter above that actually necessary to fulfil the requirements of the service is attended with a very serious expenditure of fuel.

We next come to consider the second question above mentioned, namely, the pressures best suited for working. In investigating this point it will be seen that there are three items which have to be balanced, which are as follows: By increasing the pressure (1) at what rate the time of transit is increased; (2) at what rate the volume of air required per minute is increased; and (3) at what rate the required horse power is increased. According to the foregoing Tables, a carrier in a 2¼ in. lead tube, 1,000 yards long, takes 81 sec. to pass through with 5 lbs. pressure, whereas, when the pressure is increased to 10 lbs., it goes through in 58 sec. Secondly, a carrier goes through a 3 in. lead tube with 5 lbs. pressure in 70 sec., but gets through in 50 sec. with 10 lbs. pressure. In each case the time saved in transit by employing 10 lbs. instead of 5 lbs. pressure is 30 per cent. Secondly with reference to the increased volume of air which would have to be moved, we find from the same Tables that the 1,000 yards of 2¼ in. tube requires to be supplied with 61 cubic feet of air per minute at 5 lbs. pressure, whereas 85.3 cubic feet per minute would be required when a pressure of 10 lbs. is employed. By doubling the pressure, therefore, we should have to employ 40 per cent. greater volume of compressed air; and this greater volume would be at double the original pressure (above the atmosphere), which very materially augments the work. This, then, brings us to a consideration of the third item above mentioned, namely, the increased horse power necessary for the development of this increased force. In order to produce 1,000 cubic feet of compressed air per minute, and to force the same into a container, the utilized engine performance is 24.1 horse power, when the air is compressed 5 lbs., and 51.9 horse power when it is compressed 10 lbs. Raising the pressure from 5 lbs. to 10 lbs., therefore, would increase at the same time the engine power, as appears by the above Tables, from 1.5 to 4.4 horse power for the 2¼ in. tube, and from 2.9 to 9.1 horse power for the 3 in. tube; so that in saving,

by double pressure, 30 per cent. of the time of transit, it would be necessary to burn just three times as much fuel. It is quite obvious, therefore, that the tubes should be worked with as low a pressure as is practicable.

From these relations of speed, pressure, and diameter, it is clear that by increasing the diameter to save 16 per cent. of time, it is necessary to spend twice the horse power; and that by increasing the pressure to save 30 per cent. of time, three times the horse power requires to be expended. So that if, to save time of transit, either must be increased, it is advisable to increase the pressure rather than to increase the diameter in designing a line of given length. This may be more clearly seen by a direct comparison of the two tubes which have already served as examples. The 3 in. tube being worked with 5 lbs. and the 2¼ in. with 7 lbs. pressure, would give very nearly equal times of transit, and the volume of air and horse power would be as follows:

Length in yards.	2¼-in. Lead Tubes (7 lb. Pressure).		HP.	Length in yards.	3-in. Lead Tubes (5 lb. Pressure).		HP.
	Times of Transit.	Volume of Compressed Air per Minute.			Times of Transit.	Volume of Compressed Air per Minute.	
	min. sec.	cubic ft.			min. sec.	cubic ft.	
1000	1 9	71.9	2 5	1000	1 10	119.6	2.9
2000	3 15	50.9	1.8	2000	3 19	88 5	2.1
3000	6 0	41.5	1.4	3000	6 6	72.3	1 7

In two lead tubes, therefore, of equal length, one 3 in. and the other 2¼ in. in diameter, about the same speed of transit will be obtained in both by employing 5 lbs. to work the 3 in. tube, and 7 lbs. to work the 2¼ in. tube, and in doing so there will be expended in the smaller tube with the higher pressure about 16 per cent. less horse power than in the larger tube with the lower pressure. Hence if the carriers of the 2¼ in. tube be sufficiently capacious for the required traffic, the economy resulting from the employment of the smaller sized tube is obvious.

The 3 in. tube with 10 lbs. pressure is a very unprofitable combination, and should not be employed in practice except upon very long lengths. The question of diameter and pressure, therefore, was reduced, for moderate lengths, to a comparison between the engine powers necessary to work a 2¼ in. tube with an air pressure of 10 lbs. and a vacuum of 6.5 lbs., and 3 in. tubes with a pressure of 7.6 lbs., and a vacuum of 5.475 lbs., the pressure and vacuum being worked together in cases where the traffic is sufficient for the employment of a double line, one line being used for the passage of traffic in either direction. Here, then, the question presents itself, whether it would be better, for the purposes of the Post Office requirements, to take an uniform diameter of tube throughout the whole system now required to be laid down —in which the distances range from 820 to 2,560 yards—or to take 2¼ in. tubes for lengths up to about 1,000 yards, and 3 in. tubes for the greater lengths, so as to render the times of transit more uniform. Some advantage might be gained from a combined system, supposing that the pumps and containers are so arranged that there are always available sufficient volumes of air, at, say, 10 lbs. and 7½ lbs. pressures, and at 6½ and 5½ lbs. vacuum. In order to equalize to some extent the times of transit, the tubes might be arranged and worked as follows:

	Diam. in.	Pressure. lb.	Vacuum. lb.
Lengths under 1000 yards..	2¼	7½	5½
Lengths between 1000 and 1500 yards	3	7½	5½
Lengths over 1500 yards....	3	10	6½

By this arrangement the times would be between the following limits:

System.	Shortest Line. m. s.	Longest Line. m. s.
1 entire 3 in	0 43	2 19
2 entire 2¼ in	0 44	2 22
3 combined	0 44	2 3

The combined system would therefore reduce the transit time on the longer lengths, the saving on the longest being about 12 per cent. As regards the question of horse power, it may be briefly stated

that the final volumes to be provided by the pumps would be as follows:

		lb.	Cubic ft. per minute.
1. Entire 3 in. system.	Pressure	7.6	1341 6
	Vacuum	5 475	3106 9
2. Entire 2¼ in. system.	Pressure	10	986.8
	Vacuum	6.5	1980.4
3. Combined 2¼ in. and 3-in. systems.	Pressure	10	625 8
	"	7 6	373.9
	Vacuum	6.5	1452 6
	"	5.475	1293.3

To produce in the reservoirs one cubic foot of air per minute, at the required effective pressures and vacua, the following work would have to be performed:

For pressure.	7.6 lb.	0 0381 HP.
	10 lb.	0 0519 HP.
For vacuum	6.5 lb.	0.0283 HP.
	5.475 lb.	0.0239 HP.

And the utilized engine performance requisite to produce air enough to work the proposed new system, and two existing iron lines combined, would be, for

	lb.		Total.
1. Entire 3 in.	7 pres.,	$1341.6 \times 0.0381 = 51.1$	$= 125.4$ HP.
	4.475 vac.,	$3106\ 9 \times 0.0239 = 74.3$	
2. Entire 2¼ in.	10 pres.,	$986.8 \times 0.0519 = 51\ 7$	$= 107.7$ HP.
	6.5 vac.,	$1980.4 \times 0.0283 = 56.0$	
3. Combined 2¼ in. and 3-in. systems.	10 pres.,	$625.8 \times 0.0519 = 32.5$	$= 126.4$ HP.
	7.6 "	$573.9 \times 0.0381 = 21.9$	
	6.5 vac.,	$1452.6 \times 0.0283 = 41.1$	
	5.475 "	$1293.3 \times 0.0239 = 30.9$	

In a series of experiments made on the 21st February, 1872, several of the pipes were left open at Telegraph street, both for pressure and vacuum, whilst indicator diagrams were taken of the engine and the pumps. The result, in so far as it bears upon the question of engine power, was, that in the most unfavorable instance the indicated engine power was 43 per cent. more than the sum of the powers indicated as being utilized in the pumps; this 43 per cent. being, of course, expended in friction and other unavoidable sources of loss of power. By increasing by 43 per cent. the utilized horse powers above calculated, we shall have

For the 3-in. system.....	(125.4 + 43 per ct)	= 179 HP.
For the 2¼-in. system....	(107.7 + 43 per ct.)	= 150 HP.
For the combined systems	(126.4 + 43 per ct.)	= 181 HP.

required for the three systems respectively.

From this it appears that the entire 3 in. system and the combined system would cost about equal engine powers, whilst an entire 2¼ in. system would require about 14 per cent. less power than either of the others to maintain it in action.

It will be important to compare the theoretical deductions arrived at by Mr. Sabine in his report on this subject to the General Post Office authorities, with the results actually obtained by that gentleman during a series of experiments made on the tubes, pumps, and engines at the Central Telegraph station, with the express purpose of ascertaining the degree of accordance between the practical results so obtained and the theoretical formula by which the figures given in our former article were arrived at. The experiments made were as follows:

1. Observations of the times of transit in tubes of different dimensions with different pressures.

2. Experiments to ascertain the velocity of the carriers in different parts of the same tube during a simple transit.

3. Observations of the mechanical performance by the steam engine, and simultaneously of the work indicated by the pumps when a known pressure was obtained in a given number of open tubes.

The tubes selected for the experiment were the following, which are in constant use:

		yds.	in. tube.
1. Telegraph-street to	Baltic Coffee House	570	2¼
2.	" Fenchurch-street	980	2¼
3.	" Founders-court	223	1½
4.	" Gresham House	588	1½

The experiments with the tube to Gresham House failed in consequence of the carriers sticking continually at a curve, which, when it did not entirely stop them, retarded them to such an extent as to render any observation of transit time valueless. In the other tubes the carriers did not stick perceptibly, although a slight retardation at curves probably occurred. The lengths of the tubes given above are, it is believed, only near approximations, and not entirely to be relied upon, the lines having been laid down some years ago, and the lengths of curves and entries not having been exactly measured at the time. Another source of discrepancy between the observed and calculated velocities arose from the fact that the formulæ by which the calculated values were obtained, assume the transverse sections of the tube to be

everywhere circular; whereas, in laying these tubes at those points where curves—some of which are probably rather sharp—occur, the lead tubes may have been bent into an oval section, in consequence of which the felt carrier, on arriving at the curve, would be compressed on opposite sides, and thus retarded to a greater or less degree. In order to avoid the pressure being altered by the working of other tubes, the experiments were made during hours when there was no ordinary business being transacted. In order also to keep the pressures as nearly constant as possible at the required values during each observation, one or more tubes had to be kept open, so that the pumps were always doing more work than was required by the carrier whose transit was being observed. In these experiments the pressure and vacuum gauges were inserted just within the mouths of the pipes. The gauges sometimes fluctuated between small limits, and their mean indications were, therefore, taken in the record of the tests. With the pressure experiments the air was pumped into the reservoir, in which the required pressure was obtained. After the carrier was put into the end of the tube the compressed air was turned on, and the carrier shot forward, being impelled to the end of its journey by the compressed air pumped in behind it. With the vacuum experiments on the other hand, the flow of air through the tube was constant, the air being pumped continually out of the reservoir into which the end of the pipe was conducted. The carrier was inserted in the open end of the tube, and was accelerated and carried along by the current. The carriers were those used in the regular service; they were made of felt, sufficiently tight without offering much frictional resistance. With the exception of the gauges, the apparatus used in the observations was very complete. The moments of starting and issuing were recorded automatically on a strip of paper by a Bain's chemical telegraph, which simultaneously recorded seconds from an astronomical clock, and also the revolutions of the engine. New mercurial gauges were ordered for those experiments, but they were not completed in time for use on the occasion of the experiments being carried out.

The results of the first series of experiments with the view of making observations of the times of transit in tubes of different dimensions with different pressures, are shown in the following Table, in which the calculated time of transit is also given for each tube and pressure:

Length of Tube.	Diameter	Effective Pressure.	Transit Times.	
			Observed.	Calculated.
Yards.	in.	lb.	sec.	sec.
980	2¼	9·5	62	57.8
		9·3	60.5	58.4
		9·0	62.0	59.4
		7 0	70.75	67.1
		6¾	68.0	68.3
		6½	68.5	69.1
		6⅛	70.5	69.6
		6 0	80.0 (?)	72.3
		5½	74.75	75.4
223	1½	5	11.5	10.5
		5½	11.0	10.0
			1 .25	
			11.0	
			10.75	
590	2¼	8	29.25	29.4
			29.25	
			30.5	
			30.5	
		7¾	30.25	29.8
		7½	30.50	30.3
		5½	42.5	35.3
			35.5	
			29.5	
			29.5	
			31.0	

In the last series of experiments the speeds observed with the 5½ lbs. pressure were very contradictory, varying as much as 43 per cent. This difference was due partly to irregular pressure, but principally to the insensibility of the gauge. The agreement between the calculated and the observed values in the other series of pressure trials, as well as in the following vacuum tests, is sufficiently close to corroborate the theoretical considerations on which the formulæ used in the calculations given in the former part of this paper were based:

Length of Tube.	Diameter.	Effective Vacua.	Transit Times.	
			Observed.	Calculated.
yards.	in.	in. lb.	sec.	sec.
590	2¼	8½=4.17	34.0	36.0
		9½=4.67	34.0	33.5
		9¾=4.78	31.5	
			33.0	33·0

In making the calculations as to speed it was assumed that expansion, although it undoubtedly takes place to some extent be-

hind the carriers in tubes, is so slight that the velocity may be regarded as uniform throughout the whole length; and this view was entirely corroborated in the series of experiments which were undertaken for the purpose of testing this point, in the recorded results of which there was not exhibited any difference of speed within the tube due to expansion, for although a more or less regular increase of speed was observed in some of the experiments, in others, where the carriers were drawn in the reverse direction, the speed decreased towards the end of the journey. This result indicates that the difference of the observed speed of the carriers in different parts of the tube was mainly due to the condition of the interior surface of the section in which it was passing.

Experiments were next undertaken with the engine and pumps, with a view to ascertain how much work the engine was doing, and how much of it was being absorbed by each of the pumps in order to supply a certain number of pipes with a constant stream of compressed and rarefied air. In the first series of these experiments thirteen tubes were left open in connection with the reservoirs. During the time they were left open, and the pumps working regularly, the pressures indicated by the gauges were

Pressure, 1 lb.
Vacuum, 8 in.=3.93 lbs.

whilst the mean indications of the diagrams of the pumps taken during the same experiment were

Pressure, 1.8 lb
Vacuum, 4.25 lbs.

As, however, neither the pressure nor the vacuum could be held quite constant, the difference between the two readings was probably to some extent due to their not having been made simultaneously.

The second series of experiments was made with seven tubes left open at the distant ends. The pressures indicated by the gauge on this occasion were

In the pressure pipes, 6 lbs.
" vacuum " 10½=5.16 lbs.,

and the indicator registered a mean of

Pressure, 4.25 lbs.
Vacuum, 5.16 lbs.

The results of these experiments were concisely as follows:

Series I.

	horse power.
Mean calculated performance in pressure pump	=1.26
" " vacuum "	=7.29
	9 55
Indicated by pressure pump	=1 42
" vacuum "	=8.24
	9 66
Engine cylinder (maximum)	=11.60

Series II.

Mean calculated performance in pressure pump	=3.20
" " vacuum "	=6.67
	9.87
Indicated by pressure pump	=3.10
" vacuum "	=9.10
	12.20
Engine cylinder (maximum)	=17.7

Only about 70 per cent. of the engine power in the second series was utilized in the pumps, the remaining 30 per cent. being consumed in friction and other channels of loss of power; and although the first series showed more favorably, it is probable that no better relation between lost and utilized power could be depended on with safety.

The indicator diagrams of the pressure pump in both series showed a leakage through the outlet valves back into the cylinder on the return of the piston from both ends. In the diagrams of this pump the outlet valve of the top appears to have leaked most in the first series, whilst in the second series the valve at the bottom was the worst, the loss keeping the back pressure up to nearly 5½ lbs. during ¼ of the whole stroke, and representing a loss of about 25 per cent. of the work which could have been done on that side of the piston. This pump, having a capacity of 2.78 cubic ft., at 40 revolutions, should have a maximum delivery of 212.4 cubic feet per minute at 1 lb. pressure; whereas the volume of compressed air, according to calculation, was only 165.9 cubic feet at that pressure. At the same rate, this pump might have delivered 174.7 cubic feet per minute at 6 lbs. pressure; whereas the calculation showed that only 137.7 cubic feet at that pressure passed. In each instance, the calculated volume was about 22 per cent. less than the maximum volume which the pressure pump might have delivered. The inlet valves appeared—by the tardy rise of

the pressure curve—to have leaked also. The indicator diagrams of the vacuum pump of both series showed that the valve at the top stuck at the commencement of the stroke and opened with a jerk. The diagram at the bottom was very regular, and the remainder of the valves appear to have been in good order; nevertheless, the capacity of the vacuum pump was, at the rate at which it was worked, considerably in excess of the duty which it performed.

From the results of the foregoing investigations, Mr. Sabine draws the general conclusions that, in regard to the proposed extension of the pneumatic tube system in connection with the Postal Telegraph Department:

1. The most economical results will be found from the employment of an entire 2¼ in. lead tube system.

2. The pressures best suited for working are 10 lbs. pressure, 6½ lbs. vacuum for all lengths.

3. The engine power necessary to be provided will be 150 horse power, of which not more than 30 per cent. may be used in internal friction, etc., and the remainder in providing about 1,000 cubic feet of compressed air, and 2,000 cubic feet of rarefied air per minute.

THE ARCHITECTURE OF CHINA.*

From "The Building News"

In that strange college in the Island of Laputa, which Gulliver visited in his travels, he relates, among the seemingly impossible problems on which its inmates were spending their lives in trying to solve, that one was an effort to build a house by beginning at the roof. This, curiously enough, is the Chinese method. The framework of the roof is first made on the ground in the exact spot where the house is to be, and then it is raised up and the pillars are placed below to support it, the walls being afterwards formed by filling up the spaces between the pillars with brick. Putting up a roof in this manner is suggestive of pitching a tent; indeed, it is said that the peculiar curves of a Chinese roof are an imitation of a tent form, and that this is the real origin of Chinese architecture. Such may have been the case, but now the architecture of the country is essentially wooden, and these wooden forms may be found, as in other countries, repeated in stone and marble. Many important buildings are yet wholly of wood, such as the structure on the north altar of the Temple of Heaven, and the great hall of the Ming Tombs—which last, Mr. Simpson said he believed to be one of the finest buildings in China. Stone is largely used for bridges, gateways, and for public works; while ornamental structures in gardens, and balustrades surrounding tombs and important buildings, are generally of marble. Brick may be said to be the principal building material of China. The walls of cities are built of bricks about 12 in. long. For some temples and fine building work, very small grey bricks are used; they are ground perfectly square and all to one size; so exactly is this done, that, when built, one cannot insert the point of a knife between them, and the work produced will rival the finest specimens of work in any other part of the world. Tiles are almost universally used for roofs; in palaces and temples they are often colored and glazed. There are a number of very handsome pailows about Peking, in which glazed tiles or bricks are used, producing a very fine effect, yellow and green being the favorite colors. The Temple on the Wan-sheu-shan, near the Summer Palace, Peking, is, with the exception of a marble base, wholly constructed of beautifully-colored majolica, rich and bright in effect, all covered with ornament and Buddhist figures. This is one of the finest specimens of this kind of work in existence. Close beside it is a very fine temple, all formed of bronze, almost every form of Chinese architecture being repeated very perfectly in that metal. Mr. Simpson then proceeded to describe the buildings of the British Legation in Peking, of which several large detail drawings were exhibited. The building occupied by the Legation belongs to the Duke Leeang, one of the offshoots of the Imperial family. It was called the Foo or Palace of the Duke Leeang, and is a fair specimen of Chinese architecture. All buildings of this kind

* A paper read before the Royal Institute of British Architects, by Mr. W. Simpson, F. R. G. S.

are placed upon a raised stone platform, with steps for ascent. Some of the stones forming the floor of this building are cut with circular discs as bases for the wooden pillars. The pillars are not inserted; they only rest like the pole of a tent. In more common houses, where no platform has been made, circular stones are placed below the columns so as to preserve the wood from the damp of the ground. All houses are made to face the south; there is no exception to this in palaces and better-class houses, although in the dwellings of the poorer classes it is not always attended to. The usual reason assigned for this is owing to a peculiar deification of wind and water, known as the Fung-Shuie—these words simply meaning wind and water; but they have much to do with everything in China, and control the architect as well as the sexton. A palace like the Duke Leeang's, comprises a series of buildings, each behind the other, towards the north. As the visitor passes through from the south, the successive buildings get richer in material and ornament; but there is no essential difference of constructive character. The more private rooms of a palace are those towards the north. There is only one floor in Chinese houses, and their distinctive feature is that extent of accommodation is derived from the repetition of these halls, and not from stories above or extensions on the side. Houses in India, such as at Delhi and Benares, are quadrangles, with rooms all round looking into a garden in the middle. A Pompeian house is only a variety of this. The Chinese plan is most marked in its difference. In the building occupied by the British Legation, in connection with the first of these halls on the south only a comparatively small space at each end is walled in, indicating that it has only got accommodation for some outer attendants. Passing this, each hall has more enclosed space, and the most northern are walled entirely round. The ground between each is more or less in the form of a garden with shrubs, flowers, and plants. There is still an outer wall, and one may be passing to a very fine palace in Peking, and see nothing but dirt and decay on the outside. One very distinctive feature in Chinese architecture is what, for want of a better name, Mr. Simpson called the "frieze." It reminds one of the bracket capital of Hindoo architecture, and no doubt had a similar origin. It is now a complicated triple succession of small brackets, which project forward, giving increased breadth on the top for the support of the roof. Although evidently constructive in its origin and purpose, it is the most ornamental portion, and its complexity makes it perhaps the most striking feature of Chinese architecture. All buildings with anything like architectural pretensions will be found to have this peculiar frieze. Its origin is evidently wooden; but Mr. Simpson had seen it repeated in stone, marble, majolica, brick, bronze, and iron. The celebrated tombs of the Ming dynasty, which are about 40 miles north of Peking, were next described by Mr. Simpson. A fine road with splendid bridges, now all gone to ruins, formerly communicated with the capital. On approaching the tombs from Peking, the first notable feature was a pailow, of 5 gateways, in fine white marble, much resembling the gateways of the Sanchi tope, in Central India. The wooden origin of its construction was palpable at the first glance. One of the noted features of the Ming Tombs is a long dromos, with colossal stone figures on each side. This strange approach is nearly a mile in length. There are 32 figures in all, 20 of them being animals and 12 are human. They are in pairs, opposite each other, and facing the roadway. The figures are all of stone, and although not executed in what is understood by rude art, yet they are not of a high class of work. At the end of this sculptured avenue the Ming Tombs become visible. They are called the Shi-san-ling, or the Thirteen Tombs (for that is the number of Emperors buried at this place), and they extend for some miles along the base of the hill, which forms an amphitheatre all round. The tomb of Yung-lo, the first of the Mings, buried here, is an earth mound, about half a mile in circumference. There is a retaining wall, crenellated, and about 20 ft. high all round. To the student of Indian architecture this grave heap will be of great interest, as giving almost the exact model of such monuments as the Sanchi and Manikiola topes, which were developments from the tumulus and the cairn. As all graves in China are places where offerings are made, they become, as it were, altars or temples. At an Emperor's tomb a temple is constructed for the ceremonies, and in the case of Yung-lo's tomb it becomes an important addition to the original tumulus. A rectangular space, about 1,200 ft. long by 500 ft. wide, south of the tomb, is en-

closed by a wall; within this are a number of buildings, the plan of one of which is exactly that of a "yamun" or palace, suggesting the ancient idea that the tomb, the temple, and the palace were symbolically repetitions of each other. On the top of the wall enclosing the mound, and in a line with other buildings to the south, there is a structure which contains what Mr. Simpson supposed to be the monumental tablet. This tablet or tombstone is a tall block placed erect on the back of a tortoise, as all tombstones erected by Imperial order or permission are. Further south is a wooden pailow or gate, and then a small hall. The next building to the south is the great hall—the finest specimen of Chinese architecture which Mr. Simpson had seen. This building measures 220 ft. by 92 ft. 8 in. The roof is supported by 60 pillars, 16 of which are 60 ft. high and about 11 ft. 4 in. in circumference. The others are about 40 ft. high. The wood is teak, said to have been brought from Borneo, made into a raft, and floated most of the way; but these heavy materials must have entailed a long land-carriage. Although quite four hundred years old, the pillars, in common with the whole of the building, are about as perfect as on the day they were first erected. The raised stone platform, which is the base of Chinese buildings, becomes in the important or imperial edifices a triple terrace, with a low marble balustrade. The purpose of this vast hall seems to have been that of containing the ancestral tablet of Yung-lo, which is of wood, and not above 18 in. or 2 ft. high. Having described others of the Ming Tombs, especially that of Hung-wu, the first of the dynasty, at Nanking, Mr. Simpson referred to the Temple of Heaven, at Peking, of which curious shrine he said that no adequate description yet existed in our own language. Du Halde's account of it gives not the faintest notion of the place, and his plan of it is fanciful and inaccurate. Photographers who have penetrated to the place have always given the north altar as the Temple of Heaven, whereas it is only a portion of it, and not the most important. The Temple of Heaven occupies about a square mile of ground; that is, the outer wall is about four miles round, enclosing a large space which has a park-like appearance, with avenues of trees. Here the animals kept for the sacrifice find grazing. This temple has three enclosures. The threefold division is common to temples all over the East. We have the Tabernacle of Moses and the Temple of Solomon, and the Eastern churches to this day follow this threefold division. The umbrella is an old symbol of dominion and power, and the Chatta of Buddha is triple, implying, no doubt, sovereignty over the "three worlds" which are so often referred to in the ancient Classics of India. One of the most important of the insignia of the Emperor of China is a triple umbrella, and the circular building on the north altar of the Temple of Heaven has a triple roof. The central portion of the Temple of Heaven contains two altars, which are distinguished as the north and south, the latter being the most important part of the temple. Having described these altars, and pointed out how largely symbolism enters into the construction of the building, Mr. Simpson adduced reasons for his theory that the Temple of Heaven was made in imitation of a sepulchral mound. In speaking of "pailows," Mr. Simpson pointed out their striking identity of construction with that of the gateways of the Sanchi tope, the stones being mortised into each other as if they were logs of wood. There is a very fine old arch in the village of Keu-yung Kwan, in the Nankow pass; its date is said to be about 1345. It is a triumphal monument, erected in memory of a victory. This monument has great importance to philologists, being a sort of Rosetta stone for this part of the world. It has an inscription repeated in six different characters. The first is in Sanscrit, and that is copied phonetically in Thiketan, Mongolian, Ouigour, Neuchih, and Chinese. The Neuchih alphabet was only known by name, but now a complete knowledge of the characters has been framed from this arch. That portion of the Great Wall of China at the north end of the Nankow pass is in very good condition. It is built of solid stone, with brick parapets, and is said to be 1,200 miles long. The wall which forms the enclosure of the city of Peking is much more imposing to the eye than the so-called Great Wall of China. There are 16 miles of it enclosing the Tartar city, and one 9 miles more round the Chinese city. It varies from 30 ft. to 60 ft. wide on the top. It would form a magnificent street, but no one is allowed to go upon it, and the result is that grass and bushes are growing on it like a thick jungle. The bricks of which it is built are 19½ in. long, 9¼ in. broad, and 5 in. thick. Having de-

scribed some of the pagodas, Mr. Simpson summed up by saying that to one who is intimate with the architecture of India, that of China seems poor in comparison. And yet it is important from its links of connection and as illustrating a similar wooden development, more particularly the bracket, as a wooden piece of construction which became in both cases an ornamental feature of the architecture. The original architecture of India was wooden, like that of China, and we can only guess at what it was by the stone repetitions which are left. In conclusion, Mr. Simpson described the way in which money is raised in China for building purposes. "In the streets of Peking I one day found a man in a sort of wooden sentry box; large nails had been driven into it, so that their points projected through; this prevented the man from leaning against the sides, and the only rest he had was from sitting on a board within. He was a monk, and never seemed to sleep, for he had a string with which he night and day sounded a large sonorous bell every few minutes, as a sort of advertisement of his purpose. This was that the benevolent should come forward with money; each nail represented a sum; when any one paid that sum his name was stuck up on a piece of paper, and the nail was pulled out, making it more comfortable for the hermit within. All the nails represented the necessary amount for the repair of a temple which was close behind. This is a common proceeding for 'raising the wind' for such purposes. I was told that this monk had been two years shut up, and that he would be another year before he got out of his cocoon of nails."

ON THE APPLICATION OF STEEL LINERS TO THE HIGH PRESSURE CYLINDERS OF COMPOUND MARINE ENGINES.*

By Mr. WM. ALLEN.

From "The Engineer."

For some considerable time I have been in the habit of supplying steel-tipped cylinder gauges to the chief engineers of the vessels we engined. This was done for the purpose of determining the exact amount of wear that took place during any given period; and from the data thus obtained from engines ranging from 90 to 300 horse power, I have found that the greatest amount of wear takes place in the high-pressure cylinder, this wear not being equally distributed over the internal surface of the cylinder, but, if I may use the expression, being rather oblique or devious—sometimes being athwartships the cylinder, sometimes at the top, forward, and the bottom, aft, and giving the cylinder the appearance of having some different or softer metal in its composition. I have found this "wear" in several types of compound engines, and generally in the same places. It may be said or inferred as a reason for this wearing of cylinders that the engine centres were not fair, or that they were out of line. This plausible reasoning does not hold good, for the greatest wear exists in the high-pressure cylinder, while the low-pressure cylinder bears the tool marks, and is correct to gauge. Again, the builders of the engines whose cylinders we have gauged have reputational fame for true engine building. I have also found that although the piston rods were carried through the cylinder covers, as a vertical guide to the motion of the piston, still this wear took place, and still in different places of the cylinder's surface. The results of the high-pressure cylinders so wearing in sundry places will be well known to you. I have found that our trial-trip excellence and first voyage small consumption did not continue, and that complaints, more or less loud, were sent by owners that "the consumption was increasing." So flagrant and telling had some of the reflective complainings become to us that I determined to find, if possible, the reason why in a trial trip or first voyage satisfactory results did not continue. In one instance, on a forcible complaint being made, I went to London to investigate the matter. The vessel had just come in from her second China voyage. We had the engines opened out, and could detect nothing as likely to cause a waste of steam, everything being apparently in good

* Read before the Institute of Engineers and Shipbuilders in Scotland.

order. The boilers were also examined, and found in good order. On questioning the engineer as to the condition of the engine when standing with steam on her, I was led to suspect that steam was passing, and determined on gauging the high-pressure cylinder, telegraphing to the works for the original or boring-out gauge, on receipt of which I found that on one side of the cylinder, and extending nearly half-way down, one-eighth of an inch had been worn away. We put the piston on the bottom, and on applying a straight edge to the internal surface of the cylinder, it was observed that one side of the cylinder, forward, was rounded, the other, aft (or where the ports were), was hollow. Taking out the piston packing ring, I found its thickness to be unequal also. Concluding from this discovery that the increased consumpt was due to a passing or waste of steam, we re-bored the cylinder, and inserted a liner of cast iron, of a hard mixture, and I have now the satisfaction of knowing that the first voyage data is fairly maintained, thereby proving that the deviation was partly, if not wholly, due to the wearing away of the cylinder in sundry places. From this time I began supplying engineers with cylinder gauges, and also to note if such "wearings" were isolated—the results of my observations proving, as before mentioned, that, with several types of compound engines, and by various makers, the same exists. At this period we were casting our high-pressure cylinders jacketed, and of a re-cast mixture of ten of marine scrap, seven of Summerlee No. 3, and three of cold blast. We found that this bored pretty well, not showing soft; yet when under steam and the engine running, it wore freely. I then made our cylinders of a harder mixture, and on the same arrangement, but gained no cessation of unequal wear, rather losing considerably in having two high pressure cylinders cracked, after being in the vessels one and three months respectively, which, of course, we had to replace at our cost.

About this time, two years ago, a certain *furore* was in the market, or rather the craniums of shipowners, as to steel being "the thing" for propeller blades; and it was rather amusing to see them scratch out of a specification the usual "propeller of cast iron," and substitute "to have steel blades," as if a ship could not be propelled, or the water cut, without a Sheffield blade. I thought we might be in keeping with the spirit of the times, too, by adopting or trying steel, this never-failing immortal steel, "warranted not to break until worn down," as liners of high-pressure cylinder; and with this object in view, and by way of an experiment, I sent a tracing of a shell to Vickers, Sons & Co., Sheffield, giving them a full account of what we wanted, and what we expected from their steel. Their process of casting this steel I am ignorant of, and unfortunately I have not asked them to define it, else this paper might have had some additional interest; but I dare say it will be fully known to you, or the most of you. The shell was for the high-pressure cylinder of a compound engine we were building for the steamship Achilles, of 140 horse power. It is 32 in. diameter, and having a stroke of 33 in. In due course the shell was delivered to us, and presented the appearance of a clean cast, giving a clear, bell-like ring when struck with a hammer. We carefully watched the boring, and can say that it bored very easy. Being of a close, soft-looking grain, we finished it, using soapy water during the last cast, which gave it a smooth, glassy appearance, and not having the veriest blow-hole in it, it bore all the criticism it received from inspecting engineers and others. We were continually having drummed into our ears the experiences of others with steel, and the difficulties to be met with. Some said: "The piston would seize unless there was a brass packing ring fitted!" Others, "That it would wear away the piston." One even went the length of hinting: "We would need a tallow pump attached to the engine for lubricating the steel," and so on, *ad nauseam*. In due course the engine was finished, the liner being fitted into the outer cylinder shell leaving the annular space as the jacket, and the piston was of the ordinary form and make. On getting steam up, we found that "no seizing" took place—everything working well and quietly. We had a trial trip of six hours, still no sounds of tearing were heard to verify the suspicions of the suspicious, and we did not "dose her with tallow." The vessel went her first voyage to Alexandria, thence to Odessa, thence to Dunkirk, and back to Sunderland. The engineer reported from Alexandria that no deviation had occurred with the cylinder. By his gauge it was the same as when fitted. On her return we had the cylinder

opened out and gauged by the work's boring-gauge, when it was found to be just the same as when at first bored—in fact, the tool feed marks were still there. The piston packing-ring was in every way as originally fitted. The vessel went another Black Sea voyage, and on again gauging the liner we found it in every respect the same as when fitted. And now, after eighteen months' hard running, no wear has taken place with it, or, as the engineer puts it, "he has not set out a piston spring since he left us." From this experiment it will be seen that steel for liners for compound marine engines can be used with success. In the matter of first cost there is, it is true, an increase over a cast iron liner; but when it is considered that the cast iron liner weighs heavier, and before it can be made to run for two years without wear it must be of a hardness that entails tedious and difficult boring, this cost equals, if it does not exceed, the easy-bored, light, unwearing steel liner supplied at 60s. per cwt.

I have not gone into the causes, or assumed reasonings, which can naturally be brought forward to account for the devious or erratic wearing of the internal surfaces of inverted compound high-pressure cylinders. I am not prepared to say or prove that cast iron, at a certain temperature, and under friction, undergoes any change, so that its nature is to a certain extent weakened or destroyed. I leave these profound solutions to the profound. But this I can say, that such "wearings" do take place and exist in the high-pressure or heated cylinder, while the low-pressure cylinder is virtually intact. I have gauged now some ninety pairs of compound engine cylinders by different makers, some having the jackets cast in, others having hard cast iron liners inserted, and have invariably found a substantiation of my views that the high-pressure cylinder wears soonest, while the low-pressure remains good and true.

From the above cause I attribute in a great measure the tales of increased consumpt which as engine builders we often hear or have sent to us; and I daresay there are few marine engine builders who have not felt the weight of an owner's irate pen glowing beneath an increased consumption of fuel, when the poor engine builder cowceringly seeks shelter beneath his suavity of manner, or adopts a conciliatory policy. I have purposely condensed this paper, preferring merely to give you the pith of the experiment without an array of wordy padding or long drawn-out sentences, ending in nothing and meaning the same. But if it can point out a mode of keeping the "grand trial trip data" intact for years, or if it directs your attention to a "wrinkle" in the application of steel, whereby steamship owners can be kept "sweet" over fuel matters, I shall, indeed, consider the time I have spent in making gauges, collecting data, making notes, and in writing this, as well spent.

PEAT.

From "The Journal of the Society of Arts."

As is not uncommon in the economic history of mankind, the scarcity and high price of an article indispensable to human comfort and prosperity have called into existence numerous cheaper substitutes. Since coal reached a famine price, great efforts have been made to produce fuel which, if not altogether equal to coal in compactness and calorific power, might not inadequately supply its place at a lower cost. It is true that the laws of demand and supply have already shown their power by attracting an enormous addition of enterprise and capital to the production of coal. In the north of England old pits are being reclaimed from the water, new borings are in progress, extensive submarine mines have been projected, and general activity prevails. Not less vigor is exhibited in other districts. The famous Silkstone and Barnsley seams are subjected to fresh attacks. Cannock Chase will shortly abound with new collieries, while in South Wales new companies are forming, and new shafts are being sunk almost daily. Within the next two years the output of English coal will probably be enormously increased, but in the meanwhile fuel is at a price which seriously compromises many of the most important departments of industry.

Great attention has been given to the

manufacture of various kinds of artificial fuel. The majority of these are composed of coal-dust mixed with ashes and refuse, and supplied with carbon by the addition of tar or bitumen, mixed in one case with a small percentage of farina. It is impossible to overlook the obvious truth that fuel made from coal refuse must, to a considerable extent, depend upon the coal supply, and sympathize in price with the fluctuations of the coal market, but this remark will not apply to peat, a material drawn from the surface instead of the bowels of the earth, and supplying, without any admixture of foreign matter, fuel of a high quality.

In its crude form, peat has been in use from time immemorial, and probably succeeded wood when the diminution of the primeval forest compelled man to seek for other fuel. Peat, from its greater accessibility, naturally preceded coal as a caloric agent, and although requiring preparatory treatment, was more available to the needs of the early races than coal, which requires the employment of labor and skill to withdraw it from the storehouses of nature. But no sooner had civilization supplied means for the extraction of large quantities of coal, than peat naturally fell into disuse, especially in this island, where abundance of coal on the one hand, and the difficulty of drying peat on the other, contributed to invest coal with extraordinary advantages. Coal, however, is very unequally distributed, and in many countries, notably Ireland, Holland, Westphalia, Bavaria, France, and Italy, peat, in its crude or in its prepared form, has long supplied a large proportion of the fuel of the people.

Arising from the annual growth and decay of marsh plants, peat forms the most recent link in a long chain. Wood and woody fibre are the origin and substance of peat, lignite, common or bituminous coal, and anthracite. These all mark gradual transitions from the vegetation of primeval ages to the anthracite of to-day, and are all compounds of carbon, hydrogen and oxygen, but contain these elements in very different proportions. Peat contains water to a much greater extent than coal, and as this water is, of course, opposed to combustion, its removal is the prime difficulty in the preparation of peat for fuel. Peats vary considerably in the proportion of water contained by them, but it may safely be put down as ranging from 75 to 90 per cent. As this large quantity of water is retained in multitudinous minute cells, great difficulty is experienced in getting rid of the aqueous particles.

As this is the main object of all peat preparation, the drainage of peat bogs assumes great commercial importance. An undrained bog contains about 90 per cent. of water, while a drained one holds about 80 per cent. This difference of 10 per cent. is the difference between success and failure. With equal labor applied to raising the wet peat, the out-put of a drained bog will be exactly double that of one undrained, or twenty per cent. of perfectly dry peat against ten. Not only in the proportion of water contained by them, but in other equally important respects, peats vary very much. In structure, specific weight, and admixture with mineral matter, the product of one bog differs greatly from that of another, and indeed the several strata of the same bog vary widely in quality. Nothing can be more absurd than to speak of peat, either scientifically or commercially, as if it were one uniform substance, and this consideration becomes of great weight when tests and figures are referred to. In all reports of trials the quality of peat and the precise kind of coal used should be distinctly stated, as by trying very superior peat against very inferior coal, results might be arrived at on which it would be very unsafe to rely.

As a general rule, peat improves in proportion to its depth below the surface, owing partly to the more perfect decomposition of the woody fibre, and partly to the pressure of the superincumbent mass towards the bottom of the bog; it is darker in color and denser in composition than towards the top, where it is light-brown in color, and full of imperfectly decomposed fibre. The upper part of a high bog also suffers deterioration by exposure to the air. As peat is formed by the decomposition of successive layers of vegetable matter growing on the surface, bogs grow higher year by year. In Ireland and elsewhere it is customary to divide peat fields into "high" and "low." In ponds, lakes, and sluggish streams, "low" peat is formed of reeds and aquatic grasses. This peat is often of very good quality, is tolerably homogeneous, and is comparatively free, excepting at the surface, from coarse fibre and roots of trees. High peat fields are found on mountain tops, or more frequently in slight depressions in hilly countries, and are principally composed of

mosses, and vary very much in quality, from the admixture of small roots, trunks of trees, and other objects preserved by the tannin contained in the peat. Men in armor, in a high state of preservation, have been dug out of the Solway peat mosses; and Mr. Ralph Richard mentions an instance of a Scotch Covenanter having been exhumed from a bog in Dumfriesshire.

Owing to varying conditions of formation, the quality of the peat bogs of the Scottish Highlands varies very greatly. The uppermost portion from 1 to 10 ft. down, according to circumstances, is light and open, and possesses but little heating power. On a hill top the inferior quality of the "flow," as it is called, is very marked owing to the wearing influence of atmospheric agents, which exercise a similar deteriorating power on bituminous coal when that mineral is exposed to their influence for any length of time. Beneath the "flow" is found a stratum of a much closer and denser substance, producing sound fuel, giving a good flame, and yielding a large amount of heat. Beneath this is the most valuable stratum of all. Powerfully compressed by the weight of the two upper layers, and thoroughly protected from the atmosphere, the bottom of the bog approaches much nearer to coal, and, when dried and stacked, becomes hard, black and weighty, burning with a red ash.

It will thus be seen that while the upper and most accessible layers are hardly worth the trouble of preparation, the lower stratum of the majority of "high" peat fields richly rewards any reasonable amount of labor spent in preparing it for the fire.

Unfortunately peat combines with many valuable qualities some very serious defects. Perhaps the greatest of these is its enormous bulk, necessitating so much labor in "winning" and preparing it, as to prove fatal to all commercial venture, but those undertaken under exceptionably favorable circumstances. So far as peat industry has hitherto been prosecuted, cheap labor has been shown to be an indispensable condition of success, not, however, so difficult to fulfil as might appear at the first glance, inasmuch as peat is generally found in the greatest abundance in lonely and unfrequented spots, where such unskilled labor as is to be had can generally be purchased at a low price. Of the quantity of labor required, a clear idea may be formed from the consideration of a few simple facts. Peat in its wet state—as cut from the bog—contains, as has been shown, from 75 to 90 per cent. of water, with which it parts very reluctantly. Therefore, to produce a ton of perfectly dry peat, it would be necessary to raise from 4 to 10 tons of wet material. Practically, however, it has been found impossible to dry turf in the air beyond a certain point. Even when ground, macerated, rubbed down, and compressed by most of the machinery in use, and carefully dried, peat generally retains about 14 or 15 per cent. of water, while crude peat, roughly dried in the sun, contains at least 25 per cent. when apparently "dry," and if used in that condition possesses, as opposed to ordinary coal, a calorific power of 1 to 2, weight for weight. An additional disadvantage exists in the lightness and bulkiness of crude peat; thus 1 to 4 would nearly represent the effect of peat as compared with that of coal, bulk for bulk. A cubic yard of solid coal weighs about a ton, whereas a ton of common turf would, according to quality, occupy from three and a half to four times that space. A moment's reflection on these facts will produce the conviction that rough dried peat can never be available for other than local purposes, inasmuch as, in plain English, it is simply "not worth carriage" to any great distance. From time to time improvements have been introduced in the method of treating peat, with the object of insuring more perfect desiccation and greater weight and compactness. In Ireland, where $\frac{1}{4}$th of the surface, or nearly 3,000,000 of acres, is covered with peat, furnishing the almost universal fuel of the peasantry, by far the greater proportion is prepared in a barbarous manner. Cut with a "slane" into clumsy masses, the turf is spread for drying on the undrained surface of a wet bog. It is then reared in small heaps, often packed far too closely to admit of further desiccation, and is finally built up into large piles. In some districts, however, a superior description is made. This is known as "hand turf," "foot turf," and "stone turf," and is made of block peat taken from the bottom of the bog, "footed" into mud, shaped by hand, and dried, when it acquires great solidity. In Holland and the Netherlands a somewhat similar course is pursued. As much of the peat lies under water, it is raised by dredging, conveyed to a kneading and treading floor, where it is freed from roots and other foreign sub-

stances, and is subjected to a kneading operation by workmen, who, aided by pieces of board attached under their feet, break it up, and tread it down into a uniform mass of peat pulp. This is spread on the drying ground, and after undergoing a further treading and levelling process, is shaped into a stratum about 8 or 10 in. in thickness. This is cut up into bricks, allowed to remain on its bed to shrink, until firm enough to be handled, and is then made into small piles for drying. The spreading ground, which receives the kneaded peat, is carefully levelled, and is strewn over with a layer of dry reeds or sedge, which facilitates the escape of moisture. Both the Dutch kneaded and the Irish "footed" peat are greatly superior to the crude turf, but innumerable attempts have been made to attain absolute perfection by the aid of machinery, not only in this country, but in Germany, where more than eighty attempts have been made during the present century to render peat-making a commercial success.

The main objects aimed at in the construction of the innumerable peat-making machines that have from time to time been patented, are the reduction of the peat to a homogeneous pulp by maceration, and the extraction of foreign matter. By maceration—breaking up as it does the cellular structure—more perfect desiccation can be achieved than by the hand processes previously alluded to, thereby insuring greater compactness and portability. Almost every kind of cutting and kneading machine has been tried, and a few years ago a plan was tried for rubbing the peat through a sort of colander. Very good results were attained, and excellent peat was made; but for some reason—possibly the expense of production—the venture failed to secure commercial success. From the absence of roots and coarse fibre, and the reduction of the aqueous portion by 10 per cent., the quality of machine-made peat is greatly superior to the rough-dried and hand-made varieties. Compression has been tried, but it has been found that along with the water forced from the peat-pulp were ejected certain valuable constituents, notably a gelatinous substance of great importance to the validity of the fuel. Maceration having been carried far enough, it has generally been found advisable to trust to the natural shrinkage of the peat, during the drying process, to produce sufficient condensation. The difficulty from which escape seems practically impossible is in the drying process. Peat, after due sifting and maceration, could, of course, be dried by artificial heat; but the expense of this process interposes an apparently insuperable bar to its adoption, while the climate with which the British islands are blessed or afflicted—according to opinion—renders any attempt at simple open-air drying practically useless for commercial undertakings on a large scale. Both in England and in Germany drying under sheds has been tried with considerable success, and to the construction of these sheds much ingenuity has been devoted. Shelter from the rain, and the preservation of a thorough circulation of air, are the objects to be achieved in countries where the whole year probably produces not more than a hundred good drying days.

Among the many peat-making systems now in operation, that patented by Mr. Clayton is one of the most recent. On being cut from the bog, the turf is filled into "squeezing trucks." A piston is forced against the peat in the squeezing truck by the aid of a screw and lever, effecting such pressure upon the body of the peat as to force much of the loose or "free" water out of it. The great bulk of the water, however, is locked up in the cellular structure of the fibre, and cannot be got rid of by compression, and the peat is, therefore, next subjected to a masticating process. The trucks run upon a tramway from the peat-bog to the masticating machine, and are lifted from the tramway by hoisting gear. The machine consists of a vertical chamber, in which revolves a shaft, having fixed upon it a series of screw-like blades, the action being somewhat similar to that of an ordinary pug or tempering mill. The rough peat from the squeezing trucks is fed into the hopper of this chamber, and by the action of the blade is broken up and forced downwards into the comminuting apparatus. A screening apparatus may here be introduced when necessary. Connected with this vertical chamber is a horizontal cylinder, which completes the "pulping" operation. This cylinder is fitted with a central revolving shaft, upon which are fixed propelling screws, and also a series of curved arms or discs, so arranged upon it that in their whole length they form a dissected double helix with increasing spiral. Along

the bottom of this cylinder, and projecting upwards towards the shaft, are arranged cutting blades of hardened steel, between which the discs pass in their revolution. Thoroughly masticated and reduced to homogeneity during its passage through the machine, the peat is expelled by the continued screw motion in continuous streams on to a special receiver. This consists of a number of rollers, which receive the peat and conduct it to a portable lathed tray, suitably located under the rollers, and carried on fixed wheels, of which there is a continuous forward series. The moving peat imparts motion to the tray, thus pushing it forward from under the rollers until the tray is filled with peat. This is afterwards cut up into bricks, and dried in sheds specially constructed for the purpose. These sheds are made of timber, with louvres all round, and opening in the roof, and differ very materially from the smaller sheds in use in Germany. The machine is driven by an 8 horse-power engine, requires three men and three boys to tend it, and is said to be capable of working up from 60 to 100 tons of wet peat per day.

In Germany, where peat is very well understood and extensively used for railway and other purposes, small hand-machines have long been in use for "macerating" the raw material. For mountain districts, where the manufacture of peat may be pursued with great advantage, these small machines appear to be peculiarly adapted. Six tons of wet peat, producing from a ton to a ton and a half of fuel when dried, can be prepared in these handy little contrivances in a day. An improved hand-machine, specially adapted to the requirements of the Scottish highlands and islands, and of Ireland, has just been perfected by Mr. J. A. Simpson, and combines with the simplicity of the German machine several improvements for insuring complete "mastication." The introduction of hand-machines into districts where the "footing" process now prevails, cannot fail to confer great benefit on the inhabitants, who now waste infinite time in the preparation of their winter stock of fuel.

In Canada an ingenious machine for making short work of peat-bogs was introduced several years ago by Mr. Hodges, well known in connection with the Victoria Bridge at Montreal. A large barge, fitted with suitable apparatus for cutting, cleaning, lifting, and distributing the peat, floats in a channel of water which it forms as it proceeds. Two screws in front cut and draw in the peat, and working in opposite directions, draw the barge forward at the same time. The peat cut and sucked in is subject to a masticating process, and the pulp is ejected through a long telescopic tube over the bog on each side of the channel, where it is left till dry enough to be cut and stacked.

This system appears to require the hot sun of Canada to give it a fair chance of success, and also seems to labor under the disadvantage of attacking mainly the "flow," or upper and least valuable stratum of the peat-field.

The peat-coal, as it is called, recently introduced into this country by M. Challeton de Brughat, is remarkable for its great weight and density. Although "uncompressed," it is hard, heavy, and compact in the extreme. As ordinary condensed peat resembles, when cut, a piece of oak, so does the peat coal resemble coal itself. The compactness of this new fuel, and its greater calorific power, render it very superior to the ordinary preparations of peat; but at the same time it is more costly, as some twenty shillings per ton are talked about as its selling price.

Stated broadly, the position of peat industry on a large scale is as follows:—Inasmuch as most preparations of peat (condensed or uncondensed) only possess, weight for weight, half the calorific power of coal, the successful production of bog-fuel depends upon its being sold for less than half the price of coal. Were it certain that the present price of coal could be maintained for a length of time, the manufacture of peat would offer many allurements to the capitalist. But as many high authorities agree that the influx of labor and capital into the coal trade, and the introduction of coal-cutting machinery, cannot fail, within two or at most four years, to exercise a powerful influence on the market, it is not impossible that peat may once more be severely tried by the competition of its ancient rival. One department of peat industry, however, presents a flattering aspect, be the future price of coal high or low. Peat charcoal can be produced for little more than half the price of wood charcoal, and when used in conjunction with other fuel, affords an admirable agent for the reduction of iron ore. The quality of peat charcoal, easily produced by smothered

combustion, is excellent. Being free from sulphur, the quality of iron manufactured with it is of a very high class. In former times it was the practice among the Scottish Highlanders to convert large quantities of black peat into charcoal for the use of smiths in their forges; and modern scientific authorities also attach a high value to peat charcoal, considering it for certain purposes preferable to all other fuel. Presenting an admirable field for enterprise, the manufacture of peat charcoal offers attractions other than those of a purely commercial nature.

It surely seems better, both for contemporary mankind and for posterity, to clear off the peat bogs, and convert unhealthy wastes into cornfields, than to destroy magnificent forests, which are not only grateful to the eye and valuable for innumerable purposes, but—as certain nations have found to their cost—exercise climatic influences of the most important kind.

THE COMPOUND ENGINE.

By JOHN TURNBULL, Jun.

The compound engine—whatever diversity of opinion may be held by engineers and others as to its merits as an economical expansive engine—has attracted towards itself a very considerable share of attention, from the superior results that have been obtained by it in many instances; and it is reasonable to suppose that, when a certain degree of perfection has once been attained in the manufacture of any machine, or economy secured by any new arrangement of its parts, similar machines can be so constructed as to give out the same results, if proper care is taken that the same arrangement and construction is faithfully carried out as in that of the more perfect machine. And when that degree of economy has not been obtained from a compound engine which had reasonably been expected, it would, no doubt, be found, if proper inquiry were made, that the fault lay, not in the principle that had been adopted, but that sufficient skill had not been exercised in properly proportioning the different parts through which the steam had to pass or come in contact on its way from the boiler to the condenser, and that sufficient means had not been employed to prevent or replace any waste of heat from condensation and other causes.

As the compound engine is being now so universally adopted in the Mercantile Marine Service, and a knowledge of its principles absolutely necessary by those engaged in attending it, we will, in the following remarks, explain these principles in as simple a manner as possible, and institute a comparison between the respective merits of the single-cylinder expansive condensing engine and the compound engine:

The compound engine is a high and low-pressure condensing engine, having two ordinary steam cylinders, the smaller or high-pressure cylinder communicating direct with the boiler, the larger or low-pressure condensing cylinder direct with the condenser, and both with each other. The steam is admitted freely from the boiler into the high-pressure cylinder until the piston has been moved through a certain distance where the valve is so regulated that the communication with the boiler is entirely shut off, and the remainder of the space to be passed through by the piston is performed by the expansion of the steam now shut up in the cylinder, and which, after doing its work in this cylinder, passes on to the condensing cylinder, where it does an equal or proportionate quantity of work, and then passes into the condenser.

It has been found from modern practice that when the length of stroke of both cylinders is the same, it is necessary that the condensing cylinder be about three times greater in area than the high-pressure one, and this proportion is best suited when the steam employed is from 45 to 50 lbs pressure above the atmosphere, and cutting off the steam after being admitted during $\frac{1}{3}$ of the stroke in the high-pressure cylinder. When the steam to be employed is of a less pressure, but the point of cut-off the same, then the relative proportions of the cylinders must be nearer to each other, and the reverse when steam of a greater pressure is to be used.

To get the maximum of economy out of any class of expansive condensing engine, the pressure of steam and point of cut-off must be so regulated that the steam passes

into the condenser at the end of the stroke at a pressure not exceeding 5 lbs. above a perfect vacuum, and with steam at 45 lbs. pressure above the atmosphere, which is equal to 60 lbs. pressure above a perfect vacuum (the pressure of the atmosphere being considered as equal to 15 lbs. on the square inch), and a terminal pressure of 5 lbs., we get 12 expansions, because the pressure at the end of the stroke is 12 times less than what it was at the point off cut-off, and is expressed by the formula—

$$\frac{P}{t} = R.$$

Where P = pressure at point of cut-off, t = terminal pressure, and R = ratio or number of expansions, and as the pressure of steam, accoeding to Marriotte's law, varies inversely as the space it occupies, the steam will now fill 12 times the space it originally occupied at a pressure equal to $\frac{1}{12}$th of the original pressure, that is, supposing there had been no loss of heat during the process of expansion, and this we must suppose to simplify this inquiry.

On reference to the annexed table of average pressures, it will be seen that steam admitted at 60 lbs. pressure, and cut-off at $\frac{1}{12}$th part of the stroke, exerts an average pressure = 17.32 lbs. per sq. in. on the piston throughout the whole stroke, and, although this is $3\frac{1}{2}$ times less work than would have been done had the steam been used at the full pressure of 60 lbs. throughout the whole length of the stroke, still only a 12th part of the cylinder's contents had been filled from the boiler, and the power required is thus got by working the steam expansively, at a saving equal to about $3\frac{1}{2}$ to 1. (See page 148.)

As the point of cut-off may be different from any of those shown in the table, it is as well that the student should be in possession of a simple formula for ascertaining the average pressure for himself at any time, and the following is given to find out the mean pressure during a stroke in lbs. per sq. in. Let—

L = Whole length of stroke in inches.
l = Distance travelled by piston before the steam is cut off, in inches.

R = Ratio or number of expansions = $\frac{L}{l}$.

H = Hyperbolic logarithm of R.
P = Initial pressure of steam in lbs. per sq. in
p = Mean pressure during the stroke in lbs. per square inch.

Then, $p = P\frac{1 + H}{R}$.

A table of hyperbolic logarithms is also annexed so that H may be found without any difficulty.

TABLE OF HYPERBOLIC LOGARITHMS.

The Hyperbolic Logarithm of a number is found by multiplying the common Logarithm of the number by 2.30259.

No.	Logarithm.
1-1	.0953102
1-2	.1823215
1-3	.2623642
1-4	.3364722
1-5	.4054652
1-6	.4700036
1-7	.5306282
1-8	.5877866
1-9	.6418538
2-0	.6931472
2-1	.7419373
2-2	.7884573
2-3	.8329090
2-4	.8754686
2-5	.9162907
2-6	.9555113
2-7	.9932518
2-8	1.0296913
2-9	1.0647107
3-0	1.0986124
3-1	1.1314021
3-2	1.1631508
3-3	1.1939224
3-4	1.2237754
3-5	1.2527629
3-6	1.2809338
3-7	1.3083328
3-8	1.3350010
3-9	1.3609765
4-0	1.3862943
4-1	1.4109869
4-2	1.4350845
4-3	1.4586149
4-4	1.4816045
4-5	1.5040773
4-6	1.5260563
4-7	1.5475625
4-8	1.5686159
4-9	1.5892352
5-0	1.6094379
5-1	1.6292405
5-2	1.6486586
5-3	1.6677068
5-4	1.6863989
5-5	1.7047481
5-6	1.7227665
5-7	1.7404661
5-8	1.7578579
5-9	1.7749523
6-0	1.7917595
6-1	1.8082887
6-2	1.8245493
6-3	1.8405496
6-4	1.8562979
6-5	1.8718021
6-6	1.8870697
6-7	1.9021075
6-8	1.9169226
6-9	1.9315214
7-0	1.9459100
7-1	1.9600947
7-2	1.9740810
7-3	1.9878743
7-4	2.0014800
7-5	2.0149030
7-6	2.0281482
7-7	2.0412203
7-8	2.0541237
7-9	2.0668627
8-0	2.0794414

No.	Logarithm.
8-1	2.0918640
8-2	2 1041341
8-3	2 1162555
8-4	2 1282317
8-5	2.1400661
8-6	2.1517622
8-7	2.1633230
8-8	2 1747517
8-9	2.1860512
9-0	2.1972245
9-1	2.2082744
9-2	2.2192034
9-3	2.2300144
9-4	2.2407096
9-5	2.2512907
9-6	2.2617631
9-7	2.2721258
9-8	2 2823823
9-9	2.2925347
10-0	2 3025851
11-0	2.3978953
12-0	2.4849066
13-0	2.5649494
14-0	2 6390572
15-0	2.7080502
16-0	2.7726067
17-0	2 8332341
18-0	2 8903847
19-0	2 9444497
20-0	2 9957322
21-0	3.0445437
22-0	3 0910562
23-0	3.1354964
24-0	3.1780715
25-0	3.2188757
26-0	3 2581099
27-0	3.2958495
28-0	3.3322306
29-0	3 3672992
30-0	3.4011974

In order to arrive at the merits and capabilities of the compound engine, let us first see what are the results got from a single-cylinder condensing engine of given dimensions and cutting off the steam to work with a certain number of expansions. Let—

D = Diameter of cylinder in inches,
L = Length of stroke in feet,
N = Number of revolutions of crank per minute,
p = Mean or average pressure on piston,

then, for arriving at the horse power we use the following formula:—

$$\frac{D^2 \times .7854 \times 2L \times N \times p}{33.000} = \text{horse-power.}$$

But as $D^2 \times .7854$ = area of piston, and $2L \times N$ = speed of piston in feet per minute, we will make $D^2 \times .7854 = A$, and $2L \times N = S$, the formula then becomes

$$\frac{A \times S \times p}{33.000} = \text{H. P.}$$

and supposing the cylinder to be 24 in. diameter, length of stroke=4 ft.; number of revolutions per minute=50; pressure of steam at beginning of stroke=60 lbs. (all pressures here mentioned are above a perfect vacuum), point of cut-off, $= \frac{1}{11}$th part of the stroke, or, after the piston has travelled 4 in., so that—

D = 24 inches.
2L = 8 feet.
N = 50 revolutions.
P = 60 lbs.

$p = P\frac{1 \times H}{K} = 17.32$, we get—

$$\frac{452 \quad 4 \times 400 \times 17.32}{33.000} = 95 \text{ horse-power;}$$

To distribute this power equally over the working parts of a compound engine, it is desirable that both cylinders be so proportioned that they will each give out nearly the same power, and that the thrust caused by the entrance of the steam at the beginning of each stroke be the same in both cylinders.

To attain this with an accuracy sufficient for all practical purposes, it is necessary that the condensing cylinder be larger than the high-pressure cylinder in area, by the ratio of expansion that takes place in the high-pressure cylinder; that is to say, if

a = area of piston in high-pressure cylinder,
r = ratio of expansion in high-pressure cylinder,
A = area of piston in condensing cylinder, then

$$A = a\,r.$$

So that if P = initial pressure in small cylinder, and P′ = initial pressure in large cylinder, the area of large piston, multiplied by P′, will be equal to the area of small piston multiplied by P, then $P' A = P\,a$.

But as the ratio of expansion is the same in both cylinders, and the whole ratio of expansion equal to the initial pressure in small cylinder, divided by the terminal pressure in large cylinder, we get $\sqrt{\frac{P}{t}} =$ ratio of expansion in each cylinder, and as we have already taken P=60 lbs., and $t =$ 5 lbs., we have $\sqrt{\frac{60}{5}} = 3.46 =$ differences of area of the two pistons, and also ratio of expansion in each cylinder, and consequently=r.

From the nature of the compound engine, the area opened up for the steam by the movement of the large piston is at all times decreased by a proportionate part $= \frac{A}{a\,r} = 1$, by the advancing area of small piston, so that the space actually occupied by the expanding steam is = A — 1, and from this we get the formula for ascertaining the av-

AVERAGE PRESSURE UPON PISTON DURING ONE STROKE.

For any Rate of Expansion.

Steam cut off at	Pressure in Lbs. at Commencement of Stroke—																				
	Average Pressure in Lbs. upon the Piston.																				
1/16	21	24½	28	31½	35	38½	42	45¼	49	52¼	56	59½	63	66¼	70	77¼	84	91	98	105
1/8	28½	32¾	37½	42	46¾	51½	56¼	61	65¼	70¼	75	79½	84½	89	93¼	103	111½	121½	131	140½
3/16	17½	20¼	23¼	26¼	29½	32¼	35½	38¾	41¼	44¾	47½	50¾	53¼	56¼	59¼	65¼	71½	77½	83½	89½
1/4	25½	29½	33¾	38	42½	46½	50¾	55	59½	63¼	67½	72	76½	80½	84½	93¼	101¼	110	118½	127
5/16	28¾	33½	38½	43¼	48¼	53	57½	62¾	67¼	72¼	77¼	82	87	91¼	96¼	106¼	115¼	125½	135¼	144¾
3/8	15½	18¼	20¾	23¼	26	28½	31¼	34	36½	39	41¾	44¼	47	49½	52¼	57¼	62¼	67¼	73	78¼
7/16	23	26¾	30½	34¼	38¼	42	46	49¾	53½	57¼	61¼	65	69	72½	76¼	84¼	91¾	99¼	107¼	115
1/2	27	31½	36¼	40¾	45¼	49¾	54¼	58¾	63¼	67¼	72½	77	81¼	86	90¼	99¼	108¼	117¼	126¾	135
9/16	29¼	34¼	39	44	49	53¾	58¼	63¼	68¼	73¾	78¾	83	88	92¾	97¼	107¼	117¼	127¼	136¾	146¾
5/8	14	16½	18½	20¾	23¼	25¼	27¾	30¼	32½	34¾	37¼	39¾	42½	44¼	46¾	51¼	55¼	60¼	65	69¾
11/16	29¼	34¼	39½	44¼	49¼	54	59	64	69	73¾	78¾	83¾	88¼	93¾	98¼	108¼	118¼	128	137¾	147
3/4	12¼	14¾	16¾	18¾	21	23¼	25¼	27¼	29¼	31¼	33½	35¾	37¾	40	42	46¼	50¼	54¼	58¾	63
13/16	19	22½	25¾	28¾	32	35¼	38½	41¾	45	48¼	51½	54¾	57¾	61	64¼	70¼	77¼	83¾	90	96¼
7/8	23¼	27¼	31¼	35¼	39½	43½	47½	51¼	55¼	59¼	63¼	67¼	71¼	75¼	79	87	94¼	102¼	110¾	118¾
15/16	26¼	30¾	35¼	39¾	44¼	49	53½	57¾	62¼	66¾	71¼	75¾	80	84¼	89	98	106¼	115¼	124	133¼
1	29¼	34¼	39½	44¼	49½	54¼	59¼	64¼	69¼	74¼	79¼	84¼	89	93¾	98¼	108¾	118¾	128¾	138¾	148¾
1 1/16	32¼	37¾	43¼	48¾	54¼	59¾	65¼	70¾	76¼	81¾	87¼	92¾	98¼	103¾	109¼	120¼	131¼	142¼	153¼	164¼
1 1/8	35¼	41¼	47¼	53¼	59¼	65¼	71¼	77¼	83¼	89¼	95¼	101¼	107¼	113¼	119¼	131¼	143¼	155¼	167¼	179¼
1 3/16	38¼	44¾	51¼	57¾	64¼	70¾	77¼	83¾	90¼	96¾	103¼	109¾	116¼	122¾	129¼	142¼	155¼	168¼	181¼	194¼
1 1/4	41¼	48¼	55¼	62¼	69¼	76¼	83¼	90¼	97¼	104¼	111¼	118¼	125¼	132¼	139¼	153¼	167¼	181¼	195¼	209¼
1 5/16	44¼	51¾	59¼	66¾	74¼	81¾	89¼	96¾	104¼	111¾	119¼	126¾	134¼	141¾	149¼	164¼	179¼	194¼	209¼	224¼
1 3/8	47¼	55¼	63¼	71¼	79¼	87¼	95¼	103¼	111¼	119¼	127¼	135¼	143¼	151¼	159¼	175¼	191¼	207¼	223¼	239¼
1 7/16	50¼	58¾	67¼	75¾	84¼	92¾	101¼	109¾	118¼	126¾	135¼	143¾	152¼	160¾	169¼	186¼	203¼	220¼	237¼	254¼
1 1/2	53¼	62¼	71¼	80¼	89¼	98¼	107¼	116¼	125¼	134¼	143¼	152¼	161¼	170¼	179¼	197¼	215¼	233¼	251¼	269¼
1 9/16	56¼	65¾	75¼	84¾	94¼	103¾	113¼	122¾	132¼	141¾	151¼	160¾	170¼	179¾	189¼	208¼	227¼	246¼	265¼	284¼
1 5/8	59¼	69¼	79¼	89¼	99¼	109¼	119¼	129¼	139¼	149¼	159¼	169¼	179¼	189¼	199¼	219¼	239¼	259¼	279¼	299¼
1 11/16	62¼	72¾	83¼	93¾	104¼	114¾	125¼	135¾	146¼	156¾	167¼	177¾	188¼	198¾	209¼	230¼	251¼	272¼	293¼	314¼
1 3/4	65¼	76¼	87¼	98¼	109¼	120¼	131¼	142¼	153¼	164¼	175¼	186¼	197¼	208¼	219¼	241¼	263¼	285¼	307¼	329¼
1 13/16	68¼	79¾	91¼	102¾	114¼	125¾	137¼	148¾	160¼	171¾	183¼	194¾	206¼	217¾	229¼	252¼	275¼	298¼	321¼	344¼
1 7/8	71¼	83¼	95¼	107¼	119¼	131¼	143¼	155¼	167¼	179¼	191¼	203¼	215¼	227¼	239¼	263¼	287¼	311¼	335¼	359¼
1 15/16	74¼	86¾	99¼	111¾	124¼	136¾	149¼	161¾	174¼	186¾	199¼	211¾	224¼	236¾	249¼	274¼	299¼	324¼	349¼	374¼
2	77¼	90¼	103¼	116¼	129¼	142¼	155¼	168¼	181¼	194¼	207¼	220¼	233¼	246¼	259¼	285¼	311¼	337¼	363¼	389¼
2 1/16	80¼	93¾	107¼	120¾	134¼	147¾	161¼	174¾	188¼	201¾	215¼	228¾	242¼	255¾	269¼	296¼	323¼	350¼	377¼	404¼
2 1/8	83¼	97¼	111¼	125¼	139¼	153¼	167¼	181¼	195¼	209¼	223¼	237¼	251¼	265¼	279¼	307¼	335¼	363¼	391¼	419¼
2 3/16	86¼	100¾	115¼	129¾	144¼	158¾	173¼	187¾	202¼	216¾	231¼	245¾	260¼	274¾	289¼	318¼	347¼	376¼	405¼	434¼

erage pressure in the condensing cylinder of a compound engine.

$$p' = P' \frac{H}{R-1.}$$

A table showing the relative areas of the two cylinders of a compound engine, with the average pressure in each cylinder, etc.:

P	R	P′	H	S	p′	p
30	2.449	12.25	.896	23.23	7.52	15.71
35	2.645	13.22	972	26.10	7 83	18.27
40	2 828	14.14	1 040	28.85	8 04	20 81
45	3 000	15.00	1.098	31.47	8.22	23 25
50	3.162	15.86	1.150	34 00	8.40	25.60
55	3 316	16.58	1.197	36.44	8.58	27.86
60	3.461	17.32	1 242	38.83	8.74	30.09
65	3 605	18.02	1.281	41.13	8.85	32.28
70	3.741	18.70	1.319	43.39	9 08	34.31
75	3.872	19 36	1.353	45 57	9.11	36.46
80	4 000	20.00	1 386	47 72	9.24	38 48
85	4 123	20.61	1.415	49 78	9.34	40.44
90	4 242	21 21	1.444	51 85	9 44	42.41
95	4.358	21.80	1.470	53.84	9 56	44.28
100	4 472	22 36	1 497	55.84	9.64	46.20
105	4.582	22.91	1.521	57.77	9 73	48.04
110	4 690	23 45	1.545	59.69	9.82	49.87
115	4 795	23.98	1.567	61.57	9.89	51.68
120	4.898	24.45	1.589	63.43	9 96	53.47
125	5.000	25.0u	1 609	65.32	10.05	55 27
130	5.099	25.50	1 629	67.02	10.13	56.89
135	5.196	26 00	1.647	68.77	10.21	58 66
140	5.291	26.46	1 665	70.51	10.26	60.25
145	5 385	26 93	1 683	72.25	10 32	61 93
150	5 477	27.38	1.700	73.95	10.38	63 57
155	5.567	27.84	1.716	75.67	10.46	65.21
160	5 656	28 32	1.732	77.28	10 52	66.76
165	5.744	28.72	1.748	78.93	10 58	68 35
170	5 830	29.15	1.763	80 56	10 64	69 92
175	5 916	29.58	1.777	82.14	10 70	71.44
180	6 000	30 00	1.791	83.73	10.75	72.98
185	6.082	30 41	1 805	85 32	10.80	74.52
190	6.164	30 82	1 818	86 86	10.85	76.91

The accompanying table has been drawn out for easy reference in conformity with this rule. The first column = P = the initial pressure of the steam above a perfect vacuum on entering the small cylinder; the second = R = $\sqrt{\frac{P}{t}}$ shows the relative areas of the two cylinders, and also the number of expansions in high-pressure cylinder; the third column, = P = the terminal pressure in high-pressure cylinder, gives the pressure at beginning of stroke in condensing cylinder; the fourth column, = H, contains the hyperbolic logarithms of R; the fifth, = S, gives the average pressure during a stroke in a single cylinder, for the different values of R and = $P \frac{1+H}{R}$; the sixth column, = p′, gives the average pressure during a stroke in the condensing cylinder of a compound engine, and = $P' \frac{H}{R-1}$ and the last column, p, gives the average pressure during a stroke in the high-pressure cylinder $P = \frac{1+H}{R} - P' \frac{H}{R-1}$.

Now, as the power to be given out by both cylinders is to be the same, the power that is required to be given out by A = $\frac{95}{2}$ = 47.5 horse-power, and as $\sqrt{\frac{60}{5}}$ = 3.464, $t \times 3.464 = 17.32 = P'$, and from the above formula we get $p' = 17.32 \frac{H}{R-1}$ = 8.74 lbs. average pressure per square inch on piston So that we can now get what area of piston is required to give out this power by

$$\frac{47.5 \times 33.000}{400 \times 8.74} = 450 = 24'' \text{ diameter.}$$

and as the area of the two pistons are to each other as 1 to 3.464, we get the area of small piston = 130 sq. in. = 13″ diameter.

Table of the pressure, temperature, volume, and mechanical effect of steam.

Total pressure in lbs. per square inch.	Corresponding temperature.	Volume of steam compared with volume of water.	Mechanical effect of a cubic inch of water evaporated, in lbs. raised 1 ft. high.
1.....	102 9	20868	1739
2.....	126.1	10874	1812
3.....	141.0	7437	1859
4.....	152 3	5685	1895
5.....	161 4	4617	1924
6.....	169.2	3897	1948
7	175.9	3376	1969
8.....	182.0	2983	1989
9	187.4	2674	2006
10.....	192.4	2426	2022
11.....	197.0	2221	2036
12.....	201.3	2050	2050
13.....	205.3	1904	2063
14.. ...	209.1	1778	2074
15.....	212.8	1669	2086
16 . .	216.3	1573	2097
17.	219.6	1488	2107
18	222 7	1411	2117
19	225.6	1343	2126
20	228 5	1281	2135
21.....	231 2	1225	2144
22	233.8	1174	2152
23	236.3	1127	2160
24.....	238 7	1084	2168
25	241.0	1044	2175
26.....	243.3	1007	2182
27.....	245 5	973	2189
28.....	247 6	941	2196
29	249.6	911	2202
30.....	251.6	883	2209

Total pressure in lbs. per square inch.	Corresponding temperature.	Volume of steam compared with volume of water.	Mechanical effect of a cubic inch of water evaporated, in lbs. raised 1 ft. high
31.....	253 6	857	2215
32.....	255.5	833	2221
33.....	257.3	810	2226
34.....	259 1	788	2232
35.....	260.9	767	2238
36.....	262.6	748	2243
37.....	264 3	729	2248
38.. ...	365.9	712	2253
39.... .	367.5	695	2259
40.....	269.1	679	2264
41.....	270.6	664	2268
42	272.1	649	2273
43.....	273 6	635	2278
44.....	275.0	622	2282
45.....	276.4	610	2287
46.....	277 8	598	2291
47	279 2	586	2296
48.....	280.5	575	2300
49	281 9	564	2304
50.....	283.2	554	2308
51.....	284.4	544	2312
52.....	285.7	534	2316
53	286.9	525	2320
54	288.1	516	2324
55.....	289 3	508	2327
56	290.5	500	2331
57.....	291 7	492	2335
58 . .	292.9	484	2339
59	294.2	477	2343
60.	295.6	470	2347
61.....	296 9	463	2351
62	298 1	456	2355
63	299 2	449	2359
64.....	300.3	443	2362
65.....	301.3	437	2365
66	302.4	431	2369
67.....	303.4	425	2372
68.....	304.4	419	2675
69.....	305.4	414	2378
70.....	306.4	408	2382
71.....	307.4	403	2385
72.....	308.4	398	2388
73.....	309 3	393	2391
74.....	310.3	388	2394
75.....	311.2	383	2397
76.	312.2	379	2400
77.....	313 1	374	2403
78.....	314.0	370	2405
79.....	314.9	366	2408
80.. ..	315 8	362	2411
81.....	316 7	358	2414
82.....	317 6	354	2417
83.....	318 4	350	2419
84.....	319.3	346	2422
85	320.1	342	2425
86.....	321.0	339	2427
87	321.8	335	2430
88.....	322.6	332	2432
89.....	323.5	328	2435
90.....	324.3	325	2438
91	325.1	322	2440
92	325.9	319	2443
93.....	326.7	316	2445
94.....	327.5	313	2448
95.....	328 2	310	2450
96.....	329 0	304	2453
97.....	329.8	304	2455
98	330.5	301	2-57
99.....	331.3	298	2460
100.....	332.0	295	2462
110.....	339.2	271	2486
120.....	345.8	251	2507
130.....	352.1	233	2527
140	357.9	218	2545
150.....	363.4	205	2561
160.....	368.7	193	2577
170	373.6	183	2593
180.....	378.4	174	2608

From this we can see that for a compound engine to exert the same power as a single-cylinder condensing engine with the same number of expansions in both cases, the condensing cylinder of the compound engine requires to be equal in diameter to the single condensing cylinder; and from this being the case, it is quite reasonable to say, that if the power exerted can be got from one cylinder with the steam expanded a certain number of times, it would be unwise to add to the expense of the engine by expanding the same number of times in two cylinders instead of one. But as the source of the power obtained is the heat passed into the cylinder from the boiler, and as the economical working of the engine depends on the greatest quantity of this heat that can be converted into power, it is herein where the compound engine has the advantage over any other class of engine, and we will compare the single and the compound engine from this point of view.

The steam enters the single-cylinder engine at a pressure=60 lbs. per sq. in., the temperature of which, on reference to the annexed table, will be found to be equal to 295.6 deg. After doing its work it terminates with a pressure = 5 lbs.=161.4 deg. in temperature, and consequently has cooled down the cylinder to the same temperature, so that the fresh steam on entering to perform the next stroke can only be effective at a temperature corresponding to its pressure, and it has to part with its heat until it brings the cylinder up to its own temperature, and has consequently to be supplied with new steam from the boiler to do its work.

Now the pressure at the beginning of the stroke of the high-pressure cylinder of the compound engine is the same=60 lbs. per sq. in.; but owing to the fewer number of

expansions carried out in this one cylinder, it terminates this stroke with a pressure= 17.32 lbs. per sq. in., the temperature of which will be found on reference to be 220 deg., being a difference of only 76 deg. instead of 135 deg., or just about one-half. A great part of this waste of the heat that is passed into the cylinder can be prevented by having a space round about the cylinder, and at both ends, filled with steam at the boiler pressure; but this steam jacket, as it is called, is much more effective in the compound engine than in the single cylinder engine, for this reason: It has been found from experiment that the rapidity with which two volumes of steam of different temperatures seek to equalize themselves is as the square of their difference in temperature, that is to say—that if you mix steam of 200 deg. with steam of 100 deg., and steam of 400 deg. with steam of 100 deg., the difference of temperatures of the former being as 2 to 1, and of the latter as 4 to 1, and as $2^2=4$, and $4^2=16$; the latter temperatures will seek to equalize themselves four times quicker than the former, and, as the variation of temperature is much greater in the single cylinder than in either of the cylinders of a compound engine, the heat from the steam jacket must pass through the metal with great rapidity to replace that wasted by condensation, and this it cannot do so effectively as when the temperatures are not so widely varied; and this is one of the great advantages possessed by the compound or double-cylinder engine. Another feature in which the compound engine bears favorable comparison with the single-cylinder engine is in the difference of the thrust caused by the entrance of the steam at the beginning of each stroke, and consequently on the amount of pressure or friction thrown on the crank pin and crank shaft journals, compared with the power to be exerted. If we multiply the area of piston in single cylinder by the initial pressure, we get $452\times60=$ 27,120 lbs. total pressure, or equal to a blow of fully 12 tons at the beginning of the stroke. If, in like manner, we multiply the areas of both pistons of the compound engine by their respective initial pressures we get $131\times60=7,860$ and $452\times17.32=7,828$, which being added together, gives a total pressure at beginning of stroke when both pistons are moving simultaneously=15,688 lbs.=about 7 tons or little more than one-half of that in the single cylinder, and from this it can be easily seen that as a less shock is given to the working parts by about one-half, the dimensions of these parts can be made proportionately less, and a gentler, steadier, but equally effective motion is imparted.

The compound engine, both for marine and stationary purposes, has had the position of its cylinders and the combinations of its parts arranged in many different ways, in some cases to suit the space available for its erection, and in others, according to the different ideas of the different manufacturers; but the principle being the same in all cases, an equal economy should be got if care is taken in so proportioning the passages for the steam that no undue obstruction is caused, and that proper and efficient means are employed to prevent any waste of heat as far as possible.

The principle of the compound engine was known as early as 1781, when a patent was taken out by Jonathan Hornblower for "Employing the steam after it has acted on the first vessel to operate a second time in the other by permitting it to expand itself." But Hornblower was never able to carry out the principle to be of much practical use, owing to Watt's patents being in existence at the time.

The earliest compound engine in which the principle was practically carried out was patented in 1804 by Arthur Woolf, and his style of engine has been in use almost ever since that date in France and the Continent generally, and is still constructed by many engineers in this country, and is known as "Woolf's Engine," and employed for stationary purposes only. Both the cylinders are placed together at one end of the walking beam, the condensing cylinder being at the outer end, and the high-pressure cylinder close up to it with a proportionately less stroke. This arrangement is perfectly capable of carrying out the principle equal to any other. But the great pressure it exerts on the main centre of the walking beam, owing to all the power requiring to pass from the one end of the beam to the other, has caused it to be less extensively used than otherwise might have been the case; but more especially since 1845, when a patent was taken out by Wm. McNaught, wherein this great pressure is removed from the main centre by having the condensing cylinder only at the outer end of beam, and the high-pressure cylinder between the

main centre and the crank, thus having the power equal on both sides of the main centre, and the pressure consequently merely nominal at that part. This arrangement is by far the best when the engine has to be of the walking-beam class.

Another good arrangement is carried out in horizontal engines, with both cylinders lying side by side (generally cast together in one piece), and secured to a single sole plate; both piston rods are attached to one crosshead, so that one connecting rod conveys the whole power to the crank, nothing being in duplicate but the cylinders.

In the compound engine at present so largely employed in the British Navy, the cylinders, outwardly, are the same diameter, but the high-pressure cylinder, as previously mentioned, is generally made about ⅓ less in area than the condensing cylinder. The space round the actual high-pressure cylinder being used to receive its exhaust steam until the valve of condensing cylinder opens to admit it, as the pistons do not move simultaneously, owing to the cranks being at right angles to each other.

It has been explained in the first part of this work that the nominal horse power of an engine is ascertained by assuming the mean pressure on the piston to be equal to 7 lbs. on the square inch, and the speed of piston equal to 220 ft. per minute. But as both the working pressure and speed of piston have been greatly increased since the above rule was first adopted, it fails to convey any adequate idea of the actual capabilities of the engine. Still, in all negotiations connected with the purchase of a steam engine, it is, as a rule, the nominal horse power alone that is referred to, although it is understood that with a pressure, say of about 60 lbs., and a piston speed of about 400 ft. per minute, fully six times the nominal power is got from a condensing engine.

As the term "Nominal Horse-Power" is only used when speaking of the steam engine as a marketable commodity, a particular size of cylinder may be called a certain nominal power by one maker, and a different nominal power by another, and unfair competition often takes place by two manufacturers offering for sale say an 80 horse-power condensing engine, one of whom means to give a cylinder 50 in. diameter, whilst the other calls a 40 in. cylinder the same nominal power. The rules now generally adopted in this country to determine the nominal power of the different kinds of steam engines are as follows:—

Rule to find the nominal horse-power of a high-pressure non-condensing steam engine: Square the diameter of cylinder in inches, and divide by 12, that is to say, a non condensing engine with a cylinder=30 in. diameter, is called a 75 horse-power engine nominal, although it is capable of giving out at least three times the power when a pressure of say 60 lbs. is employed, and piston speed = 400 ft. per minute.

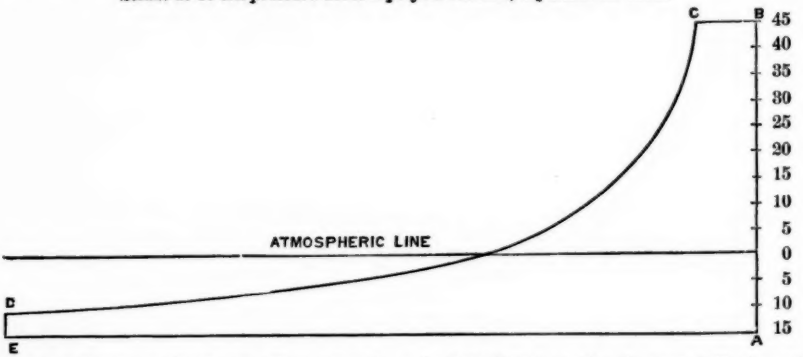
Rule to find the nominal horse-power of a single cylinder condensing engine: Square the diameter of cylinder in inches, and divide by 24, that is to say, that a condensing steam engine with a cylinder=30 in. diameter, is called a 37½ horse-power engine nominal, but is capable of working to at least six times its nominal power with 60 lbs. pressure and speed of piston=400 ft. per minute.

The rule now generally adopted by marine engineers for the nominal power of a compound engine is: Add the square of the diameter of each cylinder in inches together, and divide the sum by 30, that is with a compound engine whose condensing cylinder is 30 in. diameter, and high-pressure cylinder 17 in. diameter, is called a 40 horse-power compound engine nominal, and is also capable of working to at least six times that power with 60 lbs. pressure and speed of piston=400 ft. per minute.

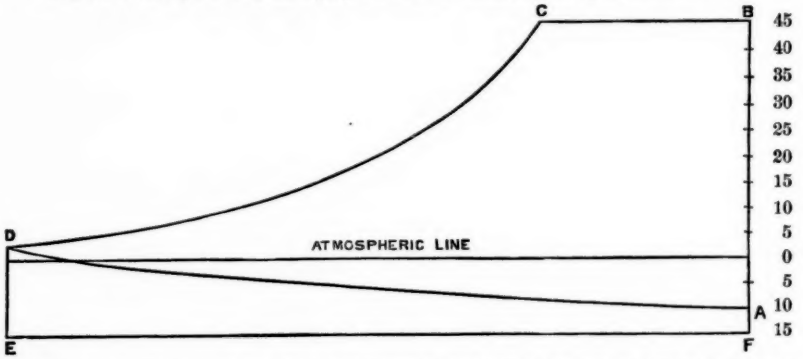
Some diagrams are herewith given, the first two of which are theoretical, and the shape that would actually be got was there no loss of heat during the stroke from condensation or other causes. In the theoretical diagram, showing the expansion curve when the steam is expanded 12 times in a single cylinder condensing engine, A B represents the total initial pressure of 60 lbs., B C the constant supply of steam from the boiler at that pressure, C the point where the steam is entirely shut off=$\frac{1}{12}$th part of the stroke, C D the expansion curve formed by the decreasing pressure of the steam in the ratio that the space it occupies is increased by the advance of the piston, D E represents the terminal pressure, and E A the line of perfect vacuum. In the compound theoretical diagram, C D is the expansion curve formed from the high-pressure cylinder, and D A the expansion curve formed from the condensing cylinder, the

line F B representing the initial pressure of 60 lbs., D E the terminal pressure in high-pressure cylinder, and initial pressure in low-pressure cylinder, and equal to 17.32 lbs., and F A the terminal pressure in low-pressure cylinder, and equal to 5 lbs.

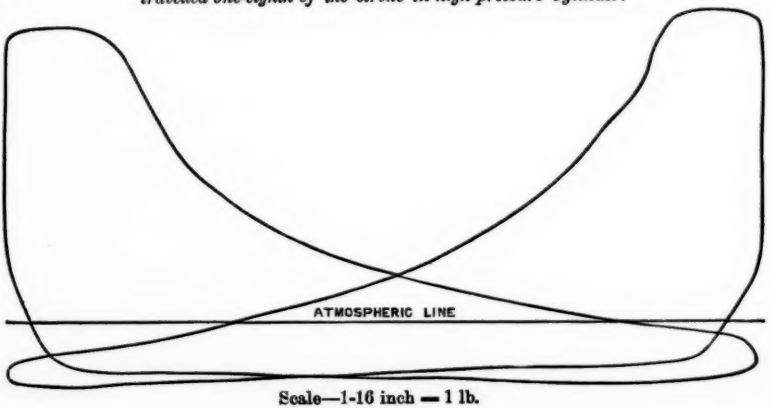
A Theoretical Diagram showing the Expansion Curve in a Single Cylinder Condensing Engine, with Steam at 60 lbs. pressure above a perfect vacuum, expanded 12 times.



Theoretical Diagrams showing the Expansive Curve in both Cylinders of a Compound Engine, with Steam at 60 lbs. pressure above a perfect vacuum. Total number of expansions = 12.

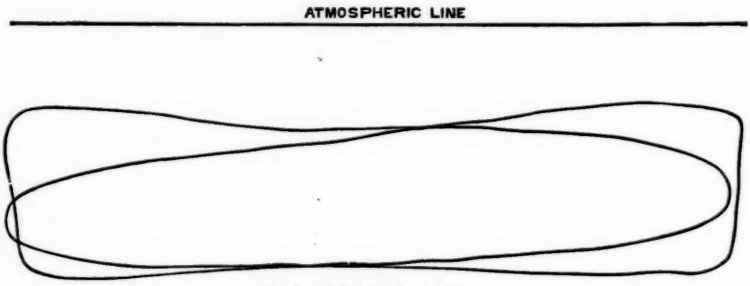


HIGH PRESSURE.—*Diagrams taken from a Compound Engine with Steam cut-off after the Piston has travelled one-eighth of the stroke in high-pressure Cylinder.*



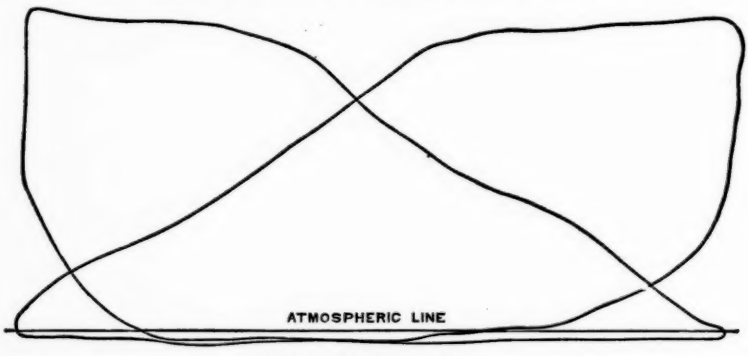
Scale—1-16 inch = 1 lb.

LOW PRESSURE.—*Diagrams taken from a Compound Engine with Steam cut-off after the Piston has travelled one-eighth of the stroke in high-pressure Cylinder.*



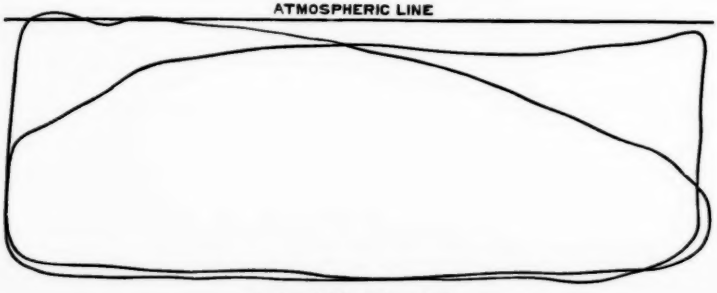
Scale - 1-8th inch = 1 lb.

HIGH PRESSURE.—*Diagrams from the Compound Engine of the S. S. "Dunluce Castle"—Steam cut-off at one-half the stroke in high-pressure Cylinder.*



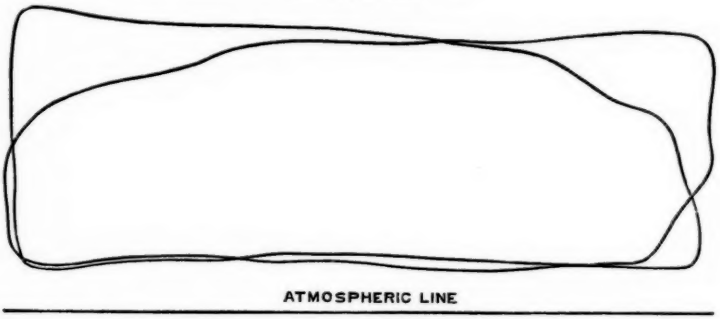
Scale—1-24th inch = 1 lb.

LOW PRESSURE—*Diagrams from the Compound Engine of the S. S. "Dunluce Castle"—Steam cut-off at one-half the stroke in high-pressure Cylinder.*



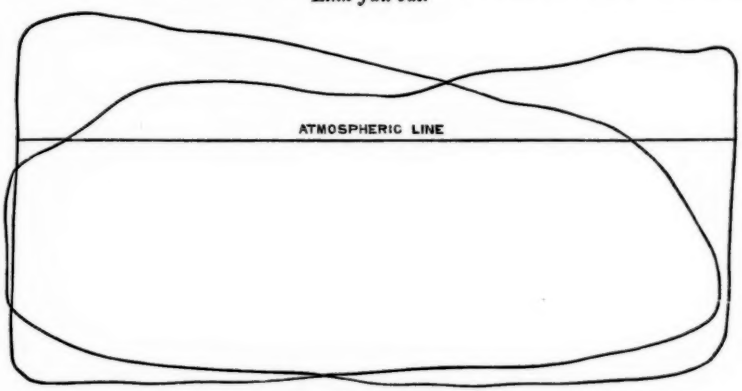
Scale—1-8th inch = 1 lb.

HIGH PRESSURE.—*Diagrams from the Compound Engine of the S. S. "Dunluce Castle, with the Link full out.*



Scale—1-24th inch = 1 lb.

LOW PRESSURE.—*Diagrams from the Compound Engine of the S. S. "Dunluce Castle," with the Link full out.*



Scale—1-8th inch = 1 lb.

ON STEAM-BOILER EXPLOSIONS.*

The subject which I propose to bring before you this evening, is chiefly interesting from its exemplifying the relation that subsists between the philosophy and the application of science. It often happens that theory follows in the wake of discovery, and that experience grows familiar with important details of practice before the abstract principle involved is sought out and clearly recognized.

In what I shall advance to-night, a different sequence will be apparent, and we shall have an illustration of the value of a scientific application of common every-day facts, in the solution of problems of the utmost moment to human life.

I allude to the property which liquids possess, of assuming the form of a globe or spheroid, when thrown upon any substance which is at a high temperature. Of this

* A paper read before the Royal Manchester Institution, by John Eddowes Bowman.

It is some years since this paper was first published. It is justly regarded as a valuable contribution to the literature of thermodynamics. As it has long been out of print, it is now reprinted as a proper supplement to our former article on the same subject.—ED.

property, a familiar instance is afforded by an experiment performed every day in our laundries. When it is required to know whether a smoothing iron is sufficiently hot for her purpose, the laundress, on taking it from the stove, applies extemporaneously a drop of moisture from her lips, and if this at once rolls off in the form of a globule, she knows by experience that the iron has reached a proper temperature; while if the drop of water bubbles and boils, however violently, it is condemned as not hot enough, and returned to the stove.

Once, then, in the flight of ages past, it was discovered that water, though it so readily boils when thrown upon a moderately hot iron, does not boil at all when in contact with metal considerably more heated.

This fact, like many others equally familiar, has been allowed to lie unexplained and uninterrogated during a long lapse of time; and it is only within the last few years that it has attracted any attention from the physical philosopher.

During my stay in Paris last winter, I had an opportunity of seeing, in the laboratory of Dumas, some experiments performed by M. Boutigny, of Evreux, who has devoted a great deal of time to the subject, and succeeded in bringing to light some most curious facts: so contrary indeed are some of his results to our preconceived ideas, that I confess I should hardly have believed them possible, if I had not witnessed them.

Some of these experiments I will now proceed to describe, showing one or two of the most remarkable by way of illustration; and before I conclude, I propose briefly noticing the important consequences of this property of water, in being the frequent cause of steam-boiler explosions.

It is generally stated in books, that a red or white heat is necessary in order to throw the water into this globular form. Far lower temperatures, however, are sufficient. This may be proved by throwing some water into a saucer of lead, a metal which melts long before it becomes luminous in the dark; the water shows no appearance of boiling, but rolls about like a little crystal ball for a considerable time. M. Boutigny, indeed, succeeded in forming a spheroid of water in a capsule floating on oil heated to not more than 340 deg., which is about 600 deg. below what is usually called "red heat."

Liquids more volatile than water become spheroidal at still lower temperatures. Alcohol, for instance, requires to be heated to 273 deg.; ether not higher than about 140 deg.; and it is found in general, that those liquids which require the highest temperature for boiling, require also the highest to make them assume the spheroidal figure.

Water and other liquids, when in the spheroidal state, slowly and gradually disappear, though no appearance of boiling is ever observed. This is of course owing to slow evaporation, which goes on from every part of its surface, thus enveloping it with a film of vapor.

Of the extreme slowness of the evaporation, some opinion may be formed from the fact, which has been proved by direct experiment, that a quantity of water which would, under ordinary circumstances, boil away at a temperature of 212 deg. in 1 min., will, if thrown into a vessel heated nearly to redness, require little less than an hour for its total dispersion.

The next point of our inquiry is one of extreme interest.

We have seen that when water is thrown upon a surface of red-hot platinum, it does not, as we might have expected, explode violently into steam, but, on the contrary, rolls calmly on its axis like a little world in space, and continues in the liquid state for a considerable length of time.

Let us, then, now endeavor to ascertain what is the temperature of the globule of water, and what relation it bears to that of the heated vessel, as well as to that of its own thin coating of vapor. And this I hope to prove by a simple experiment.

Let a large spheroid of water be formed in a tolerably thick crucible of platinum or silver, and the bulb of a small and delicate thermometer be carefully plunged into the middle of it, taking care not to allow it to come in contact with the heated metal. The temperature of the water thus ascertained is invariably 205 deg.

Perhaps one of the most curious facts which have been established in connection with this subject, is, that any variation in the temperature of the vessel containing a spheroid, does not affect the temperature of the spheroid itself. Thus it is found that a spheroid of water, when contained in a crucible heated considerably below redness, is just as hot as one contained in a crucible intensely heated to whiteness in the most powerful blast furnace!

From numerous experiments, indeed, with water, alcohol, ether, and many other liquids, the following law may be deduced: "That bodies in the spheroidal state remain constant at a temperature below that of boiling, however high the temperature of the containing vessel may be."

Pure alcohol, which, under ordinary circumstances, boils at a temperature of 173 deg., never rises, when in the spheroidal state, higher than about 170 deg.; and ether, whose usual boiling point is about 100 deg., and which almost boils with the heat of the hand, cannot be induced, when thrown into a crucible heated to whiteness in a smith's forge, to rise above 95 deg.

The same remarkable results are obtained if, instead of pouring the liquids while cold into the red-hot vessels, they be absolutely boiling at the moment; strange, and almost incredible as it may appear, the instant they reach their fiery resting place, they absolutely become cooler, and, as it were, shaking off the trammels of all known laws of nature, cease to boil!

Liquids, then, when in that peculiar physical condition which I have called spheroidal, always remain at one definite temperature; and this temperature is invariably, in the case of every liquid, lower than that at which, under ordinary circumstances, that liquid boils. Let us inquire a little more narrowly into the consequences of this law.

Dr. Faraday, by a simple and ingenious contrivance, succeeded, some years ago, in condensing into the liquid state, several of the gases which had, up to that time, resisted all such attempts, and had consequently been considered permanent gases, such as the air we breathe. This was the case with carbonic acid, chlorine, ammonia, sulphurous acid, and a few others. So great is the elastic force of these liquefied gases, or in other words, so prone are they to boil, and to pass again into the gaseous form, that a very great pressure is necessary to prevent their doing so; and unless the tube or other vessel containing them were very strong, it would probably be burst with a most violent explosion. Now it will readily be understood how it happens that these condensed liquids, unlike water and most other fluids, do not require the application of artificial heat to make them boil, but, on the contrary, continue to boil, even when cooled very far below the usual temperature of the air. Let us then inquire whether any of these liquids, whose boiling points are far below that at which water freezes, be subject to the same law as water is subject to, when they are thrown into a vessel sufficiently hot to cause them to pass into the spheroidal state.

The gas which is most easily liquefied of those which I have alluded to, is sulphurous acid, which requires, at a temperature of 45 deg., a pressure equal to two atmospheres (or about 30 lbs. to the square inch of surface), to prevent it boiling. If this pressure be removed, violent ebullition takes place; and it has been found that even when cooled as low as 14 deg. of Fahrenheit's thermometer, or in other words, 18 deg. below the melting point of ice, it boils in precisely the same way as water boils when heated to 212 deg. Fourteen degrees, then, is the boiling point of sulphurous acid.

But we have found that when liquids, even while boiling, are thrown into a heated crucible, they become cooler, and remain constant at a temperature a few degrees below their boiling point. What then will be the effect of pouring into a red-hot crucible a few drops of liquid sulphurous acid?

The experiment which was selected for the purpose of furnishing an answer to this question, is perhaps one of the most striking and apparently paradoxical in the whole range of physical science. Liquid sulphurous acid is subject to the same remarkable law as water and other liquids, in being invariably, when in the spheroidal state, at a temperature lower than its boiling point, which is 14 deg. of Fahrenheit's thermometer; so that if a spheroid of sulphurous acid be formed, it remains constant at a temperature of about 12 deg., even though the crucible containing it be at a red or a white heat. If a little water contained in a small glass bulb, $\frac{1}{4}$ or $\frac{1}{10}$ in. in diameter, be immersed in the spheroid of acid, it is almost instantly frozen, thus affording incontestable evidence of the remarkably low temperature of the spheroid.

Most persons have seen the well-known lecture-table experiment of causing water and other liquids to boil in vacuo at temperatures considerably below their ordinary boiling points; a result depending upon the diminished pressure on their surface. When liquids in the spheroidal state, however, are placed under the receiver of the air pump, and the air removed, no sign of boiling is ever perceived. We may there-

fore suppose that the temperature of the spheroid in vacuo is lower than when exposed to the atmospheric pressure, as otherwise ebullition would inevitably take place; but I am not aware that the temperature has ever been examined with a thermometer under these circumstances, and it would be by no means easily done.

I shall probably scarcely be believed when I say that even liquid sulphurous acid does not, when contained in a red-hot vessel, and in the spheroidal state, boil in vacuo.

If a thermometer be held in the atmosphere of vapor which surrounds a spheroid of water, it will give a far different result from that ensuing from its immersion in the globe itself.

Instead of indicating, as before, the temperature of 205 deg., however hot the crucible may be, the degree at which it stands will now be found to depend entirely on the temperature of the latter. If it be heated to 400 deg., the thermometer will rise to that point; or if the crucible be raised to a red heat, a mercurial thermometer, graduated to 600 deg., is instantly burst, showing a temperature considerably higher.

We have proved experimentally, that when water is thrown into a red-hot crucible, it does not, as common sense would have foretold, begin to boil, but remains constant at the temperature of 205 deg. so long as it retains the spheroidal form, however high the temperature of the crucible which contains it may be; but that the vapor surrounding it is, on the contrary, always about the same temperature as the crucible.

This comparatively low temperature of liquids in the spheroidal state, is generally attributed to the coating of vapor round the spheroid, being incapable, as it is conceived, like all other gaseous bodies, of conducting heat.

This explanation, however, though ingenious, does not meet all the difficulties of the question; for besides the heat which would be conducted by the coating of vapor, if the vapor had the power of conducting it (which is possible), there is the enormous quantity of radiant heat, emanating from all parts of the heated crucible.

If a vessel containing water be placed near a fire, it is well known that it gradually becomes warm, and if the fire be a good one, and the distance not too great, the water will shortly boil. The heat which causes the water to boil in this case, is not conducted from the fire to the water through the intervention of the air, since we know that air has no such power; but it is a portion of that which, like light from a candle, radiates from the fire in all directions, and is absorbed more or less completely by any substance which stands in its way and intercepts its passage. Why, then, does not the spheroid of water, sursounded as it is almost completely by an intensely heated metal, absorb the rays of heat which dart towards it from every side, become instantly heated to the boiling point, and dispersed in vapor with explosive violence?

In order to answer this question, it has been stated by some philosophers, that the radiant heat, when it meets with any liquid in the spheroidal state, passes through it without experiencing any interruption, and consequently does not impart any heat to it. A simple experiment is sufficient to show the fallacy of this hypothesis.

If a crucible be made red-hot, and a small bulb of glass containing water be brought near to its inner surface, the water boils violently, owing to the absorption of radiant heat, and notwithstanding the presence of a quantity of non-conducting air between the heated metal and the water. This shows that heat does radiate from the sides of the crucible, and that, too, in sufficient quantity to cause water to boil with considerable violence. If now the same crucible be again heated to an equal degree, and a few drops of water poured in, they at once assume the spheroidal state. Things being in this condition, let the little glass bulb containing water be immersed in the spheroid, and it is found that the water does not show the slightest tendency to boil. The spheroid of water has consequently in some way or other prevented the rays of heat reaching the glas bulb and the water which it contained.

But if, according to this hypothesis, the radiant heat passed through the substance of the spheroid, without being to any extent absorbed or arrested by it, it would obviously reach the bulb containing the water, and cause it to boil with as much violence almost, as it does when no spheroid is interposed between it and the source of heat.

Another mode of explaining the low temperature of liquids in the spheroidal

state, is clearly pointed out by the result of this experiment, which proves, I think, beyond all doubt, that bodies in the spheroidal state have, when they have attained their maximum temperature (which we have found to be always lower than their boiling point), the remarkable property of reflecting, almost completely, radiant heat.

A curious variation of the last experiment, tending to the same conclusion, may be made by putting a piece of ice into the red-hot crucible. It instantly absorbs sufficient heat to cause a portion of it to become spheroidal, after which it continues at a temperature of 205 deg., even though a portion of the ice remain unmelted within the globule.

Thus the ice, and afterwards the water, which has an almost perfect reflecting power at 205 deg., absorbs, instantaneously as it were, all the heat necessary to raise it to that temperature, and above which it does not become heated! Why and how is this? are questions which in the present state of our knowledge cannot be answered; and we have here one of those deep mysteries, so frequently met with in our researches into the hidden laws of nature, which baffle and confound the reason, and set at nought, for a time at least, the powers of the human mind.

We have seen that not only water, but also alcohol, ether, and liquid sulphurous acid may be obtained in the peculiar condition which I have, on account of the external form which always attends it, called the spheroidal state. It becomes interesting to inquire whether so remarkable a change may be produced in other liquids.

A great number of experiments have been made with almost every kind of liquid; solutions of acids, alkalies, and salts; compressed gases and melted solids; fats and oils of every kind, both volatile and fixed; and they tend to show that all liquids, with scarcely an exception, pass, under favorable circumstances, into the spheroidal state.

The temperature necessary to produce this effect, appears to bear some relation to the boiling point: those which boil most readily, requiring a lower temperature than the less volatile substances.

That a drop of water or other fluid when in the spheroidal state, is poised as it were, without support, at some sensible distance from the surface of the vessel containing it, may be proved in many ways.

If a spheroid of some opaque substance be formed on a nearly flat surface, and then interposed between a lighted candle and the eye, the image of the flame is distinctly seen between the hot surface and the globule. This effect might be produced if the spheroid were in a state of rapid motion up and down, since the image of the candle, seen during the ascent, would remain visible till the next ascent; just as an ignited point in rapid revolution appears as a circle of light.

That this is not the case, however, may be shown in another way. If silver be touched with nitric acid, it is rapidly corroded, and in a short time dissolved. But if a quantity of nitric acid be poured into a crucible or dish of silver, sufficiently hot to induce the spheroidal state, no corrosion whatever will take place; clearly proving that the acid is at no time in absolute contact with the metal. That this is not owing to any deficiency in the strength of the acid may be seen by placing in the spheroid a piece of cold silver, when violent action of course takes place, nitrous fumes being given off, and nitrate of silver formed.

A remarkable effect may be produced, owing to this repulsion between liquids and heated solids, if a large spheroid of water be formed on a surface nearly flat, and a small bar of white or red-hot iron be then thrust into the middle of it. Contact being impossible between the bar and the water, the latter forms a ring at some little distance from the heated bar, presenting very much the appearance of Saturn and his ring. Whether any real analogy exists between the two effects, or whether the causes be in any way connected, further researches into the nature of that anomalous appendage of the planet may perhaps decide.

I have now passed in review the most important phenomena presented by water and other liquids when thrown into vessels raised to a high temperature.

We found in the first place, that water may be made to assume the globular form, when placed in a cup heated only to 340 deg., which is less than 130 deg. higher than its boiling point; and that the temperature necessary to convert other liquids into spheroids bears some proportion to their several boiling points; that for alcohol being 273 deg., and for ether 140 deg.

Secondly, we found that the rapidity

with which water in the spheroidal state evaporates, is in proportion to the temperature of the heated vessel containing it; but that the evaporation in the spheroidal state is, at a temperature of 400 deg., 50 times more slow than that of ordinary boiling water at 212 deg.

On inquiring into the temperature of liquids in the spheroidal state, we arrived at the remarkable result, that whatever the temperature of the containing vessel may be, that of the spheroids is invariable, and always below their boiling points. Thus a spheroid of alcohol always stands at 170 deg., or 3 deg. below its boiling point; one of ether, is always 5 deg. below, or 95 deg.; and liquid sulphurous acid, which boils at 14 deg., never reaches even that low temperature when in the spheroidal state, but continues far colder than melting ice, even though the crucible in which it lies be all the time at the most intense white heat!

Fifthly, we found, that the only way of explaining this low temperature of spheroids, is to suppose that they have the property of reflecting, in a very perfect manner, the radiant heat emanating from the sides of the hot crucible, and are in this way protected from the scorching rays which would otherwise cause them to burst violently into steam.

In the sixth place it appeared that, with scarcely any exceptions, all liquids may be made to pass into the spheroidal state.

And, lastly, there appeared strong evidence to prove that spheroids are never in absolute contact with the vessel containing them.

Let us now endeavor to draw from our inquiry, something of a practical, and therefore, perhaps, more interesting character, with reference especially to the subject of steam-boiler explosions; a subject on many accounts of so much importance, that no words of mine are needed to enlist your attention for a short time to it.

Until the last few days, I had supposed that no one had attempted, previously to M. Boutigny, to account for the explosion of boilers on the supposition that the water in them passes, under certain circumstances, into the spheroidal state. In this opinion, however, I find that I was partially mistaken; and I feel great pleasure in saying that one of our townsmen, Mr. Robert Armstrong, some few years ago, advanced an idea on this subject, a good deal similar to that of M. Boutigny.

If heat be applied to water contained in an open boiler, the temperature of the water will of course continue to rise until it reaches 212 deg., when the elastic force of the steam is sufficiently great to overcome the pressure of the atmosphere, and the water boils. If the heat be still continued, the whole of the water will, as is well known, boil away, leaving the vessel empty; but as long as any liquid remains, the temperature of the vessel never rises above 212 deg., owing to the absorption of heat by the steam.

As soon as the boiler is empty, however, its temperature of course rapidly rises, and may reach a red, or even white heat, provided the furnace be sufficiently powerful.

If water be now gradually thrown into the overheated boiler, we know from what has already been said, that it will pass at once into the spheroidal state, and will continue at 205 deg., until, from some cause or other, it is permitted to *come in contact* with the heated surface, when violent ebullition immediately takes place, an enormous quantity of steam is instantaneously produced, and, if the vessel be a closed one, as is the case with steam boilers, *an explosion* is the almost inevitable result.

An experiment exceedingly easy of performance is sufficient to illustrate this. Let a large spheroid be formed in a vessel of platinum, or copper; so long as the heat is applied to the latter, the water never shows the least sign of boiling; but if the lamp be extinguished, and the vessel allowed to cool a little, the water suddenly comes in contact with the metal, and an enormous quantity of steam is instantly formed.

A spheroid composed of between four and five pints of water has been, in this way, experimented with, when the sudden formation of highly elastic steam was very striking.

If water be boiled for some time in a copper flask or small boiler, until the whole of the air is expelled, and the vessel be then tightly corked, and the source of heat removed, it is well known that as the water cools, and the vapor condenses, a partial vacuum is formed; and owing to the external atmospheric pressure, the cork is held firmly in its place, and offers considerable resistance to any attempt to withdraw it.

Far different, however, is the effect produced, if, instead of boiling the water in a comparatively cool flask, it be thrown into

one which is sufficiently hot to cause it to pass into the spheroidal state.

So long as the flask continues hot, nothing remarkable occurs; but if the lamp be removed, and the temperature of the metal be allowed to fall lower than 350 or 400 deg., a faint noise is shortly heard, and the moment after, a violent explosion takes place, projecting the cork or stopper from the mouth with great force.

Now all this is easily explained. The water, on ceasing to be spheroidal, *wets*, or comes in contact with, the heated boiler, is converted instantaneously into steam, which, being thus generated in vast quantity, finds an outlet at the point of least resistance.

This experiment proves, that if water exists in the spheroidal state in a boiler, and the boiler be allowed to cool, owing to the extinction of the fire, *an explosion* is the almost certain consequence.

A result precisely similar is produced by adding a quantity of cold water to a boiler containing a portion of liquid in the spheroidal form.

If now we multiply a few hundred times the dimensions and capacity of our puny apparatus here, we shall arrive at the size of the steam-engine boilers commonly in use; and when we remember that every cubic foot of water which is in this way suddenly converted into steam, increases in bulk no less than 1,700 times in almost a single second, and, consequently, requires 1,700 cubic ft. of room to contain it, we shall not be surprised that the strongest and best constructed boilers are burst by so sudden and so enormous an expansive force.

But here the question arises—does water really ever become spheroidal in steam boilers? and if it does, what are the circumstances which lead to so dangerous a crisis?

That water contained in boilers does pass to the spheroidal state, there can be no doubt; since we know that sometimes circumstances are such that it could not possibly be otherwise; and, moreover, it has actually been seen to be so. What then are the causes which lead to this occurrence?

The most obvious cause is a deficiency of water in the boiler; owing either to the negligence of the engine man, or to some defect or derangement of the feed pipe. When this deficiency occurs, the boiler, if the furnace underneath be in action, shortly becomes strongly heated, and it is, I believe, by no means an uncommon occurrence for it to reach even a red heat. If water, under these circumstances, be thrown in, the first portion becomes, of course, spheroidal, and continues so, until by the addition of a larger quantity, the boiler be so far cooled as to be unable to maintain the spheroidal form of the water; no sooner is this the case, than the spheroid comes in contact suddenly with the overheated boiler, bursts into steam, and in all probability, an explosion is the result.

Another, and highly probable cause of water becoming spheroidal, I find suggested by Mr. Armstrong, in his excellent work on Steam-Engine Boilers, and which is well worthy of notice. I cannot do better than use his own words. After alluding to the subject of boiler incrustations, and the effect they have in preventing the passage of heat from the furnace to the water, owing to their nonconducting property, he says:

"Under similar circumstances to those just mentioned, there can be no doubt that a portion of the boiler occasionally becomes nearly red hot, although this condition appears extremely inconsistent with the supposition that it is at the same time covered with water; yet we have been compelled to adopt this conclusion from having had ocular demonstration of its possibility, as well as other reasons. We had frequently heard the fact stated by intelligent engine men, and had been called, more than once, to witness it, although even then inclined to consider it a mistake, owing to the difficulty of ascertaining it clearly; for a slight approach to the incandescent state must be nearly invisible, owing to the strong glare of light from the furnace directly beneath, while any degree of heat much higher would be sure to weaken the iron so much as to cause the boiler bottom to give way.

"The probability of boilers sometimes approaching a red heat receives a corroborative proof on examination of the iron plates, in cases where the boilers have bulged out, and which exhibit an appearance well known to boiler-makers, by a peculiar color in the iron surrounding the part which has been red hot.

"Whenever," he continues, "a boiler is seen in this state, of course the only method of avoiding danger is to slack the fire imme-

diately by opening the fire doors. But it frequently happens that the fireman thinks the boiler is empty, and if he has an opportunity he immediately lets into it a quantity of water, when the consequence uniformly is, that the boiler bursts instantly."

The bursting in this case we can now readily understand. It is precisely similar to our last experiment, in which the spheroidal state of the water was destroyed by the addition of a quantity of cold water.

Mr. Armstrong goes on to say:—

"From what we have stated above as the common practice in some districts, we may conclude, that the principal cause of boilers becoming unduly heated, is undoubtedly, in a majority of cases, owing to the interposition of indurated or encrusted matter between the heated iron and the water; and the manner in which those circumstances operate in producing an explosion, appears to be as follows: We have before shown that an internal coating of boiler scale is liable to crack and separate into large pieces, which are thrown off from the boiler with a certain degree of violence, at some particular degree of temperature, depending upon the thickness of the scale, and the kind of substance of which it is formed."

He then proceeds to explain how, by the sudden separation of these pieces of encrusted earthy matter, the water flows upon the overheated metal, when, of course, the result will be, that a portion of the water becomes spheroidal, which, on subsequently coming in contact with the hot surface, is immediately converted into steam.

Seeing, then, the imminent danger which always attends the presence of spheroidal water in a boiler, it becomes a question of the highest importance, whether any means can be devised, which will effectually prevent such an occurrence.

If it were possible to insure a constant, uniform, and never-failing supply of water to the boiler on the one hand, and to prevent the accumulation of earthy sediment or crust, on the other, there would be little or no fear of the water ever becoming spheroidal. But there are, I believe, great and serious obstacles in the way of these conditions being practically complied with; both on account of the liability to derangement which affects most kinds of feeding apparatus, and the great difficulty which exists, both in preventing and removing the deposition of the earthy matters which are found more or less abundantly in most kinds of natural water.*

It has been found that the more smooth and even the surface of a metal is, the more prone is water or any other liquid, on being thrown upon it, to pass into the spheroidal state; and that any great roughness, or especially the presence of sharp points, considerably lessens the danger of such a change. There is, however, a great objection to fixing projecting points in a steam-engine boiler, on account of the difficulty they would occasion in cleaning it out; and the idea occurred to M. Boutigny, which is, I think, a good one, of placing in the boiler loose pointed pieces of iron of such a shape that one of the points should always be uppermost.

Before I conclude I will say one word respecting the possibility of preventing an explosion, even when water *has* become spheroidal in a steam boiler.

And here an experiment which we have already seen will suggest the best mode of proceeding, in order to avert the impending danger. When water was thrown into a hot platinum crucible, and thus made to assume the spheroidal form, we found that so long as the crucible continued hot, the globule floated on its bed of vapor, slowly and gradually evaporating, and showing no appearance even of boiling, still less of passing explosively into steam; but no sooner did we allow the crucible to cool down to a certain temperature, than the water, on touching its still overheated sides, was instantly dissipated in the form of highly elastic steam.

If, then, it be ascertained that the water in a boiler has become spheroidal, the chief care of the engine-man should be to keep up the fire, and also to prevent most completely the influx of any further supply of water; since non-compliance with either of these conditions would cause the cooling of the boiler, the spheroid would then, in all probability, shortly be converted suddenly into steam, and an explosion would be the almost inevitable result. But if, on the other hand, the spheroid be *not* allowed to touch the boiler, it will calmly and slowly evaporate, without occasioning any further inconvenience than rendering the engine

* As most kinds of spring and river water contain in solution some earthy matters, which are left by the evaporation of the water, giving rise to the formation of sediments and incrustations, it has often occurred to me that rain water might be substituted with great advantage.

comparatively inactive until it has returned to its natural condition.

The advice then relative to this subject, which should be given to those who have the charge of steam-engines, is simply this:—

1st. Be careful that the boiler is kept as free as possible from earthy incrustations, which, if allowed to accumulate, form in fact a boiler of stone inside the iron one, and thus retard the passage of heat from the fire to the water, until the iron has become more or less overheated.

2dly. Never let there be a deficiency of water in the boiler, since, when that happens, the latter may become heated almost indefinitely, and is consequently sure to render water spheroidal when thrown in, when an explosion will be (without great care) almost certain.

And lastly, If it be known that, owing to any cause, the water in a boiler has already become spheroidal, instantly stop the supply of water, and take care that the fire is well kept up until the whole of the water has evaporated; when that is the case, the boiler should be allowed to cool to its natural temperature, when water may be added and the fire re-kindled.

Mr. Stuart, in his interesting "History of the Steam-Engine," speaks of that paragon of human art in the following terms. He says: "It has become a thing alike stupendous for its force and its flexibility; for the prodigious powers which it can exert, and the ease, precision, and ductility with which they can be varied, distributed, and applied. The trunk of an elephant, which can pick up a pin and rend an oak, is nothing to it. It can engrave a seal and crush masses of obdurate metal, like wax, before it; draw out, without breaking, a thread as fine as gossamer, and lift a ship of war like a bubble in the air. It can embroider muslin, forge anchors, cut steel into ribbons, and impel loaded vessels against the fury of the winds and waves.

"It would be difficult," he continues, "to estimate the value of the benefits which these inventions have conferred upon the country. There is no branch of industry that has not been indebted to them; and in all the most material they have not only widened most magnificently the field of its exertions, but multiplied a thousand fold the amount of its productions. It is our steam-engine that has fought the battles of Europe, and exalted and sustained the political greatness of our land; and it is the same great power which now enables us to maintain the arduous struggle in which we are still engaged against the skill and capital of all other countries.

"But these are poor and narrow views of its importance. It has increased indefinitely the mass of human comforts and enjoyments, and rendered cheap and accessible, all over the world, the materials of wealth and prosperity; it has armed the feeble hand of man, in short, with a power to which no limits can be assigned, completed the dominion of mind over matter, and laid a sure foundation for all those future miracles of mechanical power, which are to aid and reward the labor of after generations."

Such is Mr. Stuart's eloquent summary of the powers and capabilities of the Steam-Engine; words, highly colored, it is true, but which are the words, nevertheless, "of truth and soberness."

We must not forget, however, that the possession of such a machine imposes upon us who benefit by it, responsibilities of no common kind; and that it is our duty, no less than our interest, to endeavor, by all the means in our power, to prevent the occurrence of those appalling explosions (still, alas! so frequent) which are attended with such fearful consequences to human life.

CALIGNY'S APPARATUS FOR RAISING WATER OR FOR DRAINAGE BY THE ACTION OF WAVES.

Translated from "Les Mondes."

Since the 22d of last July Caligny has published five notes on the motion of waves in the "Comptes Rendus" of the Academy of Sciences, forming together a complete memoir. It is necessary to read all to get a precise idea of their bearing. The note of July 22d, deals principally with experiments and observations upon the effect of waves, and of currents in the funnel-like passage formed by convergent dikes; as projected

by the Captain of the Cialdi, for the purpose of destroying or preventing the formation of sand bars.

The note of October 7th, is an investigation of the system of M. Cialdi, *i. e.*, of the effects of the lateral communication of the movement of a current of water across a reservoir. The mode of formation of sand bars is favorable to the operation of Cialdi's system.

The note of January 6th is equally important and interesting. Its special object is the study of the alternating currents that result from the blows of a water-ram.

That of the 17th of February refers to the works for drainage of the marshes at Ostia, by Moro, upon a principle like that published some years ago in the "Bulletin of the Philomathic Society" of Paris. By means of the alternating rise and fall of the level of waves, he caused the lowering of the water in the marshes below the level which the sea would have had, if there had been no waves. Notice is taken of the effect of alternating currents produced by waves on inclined shores. He mentions the fact that Moro by means of Cialdi's method removed a bar at the mouth of a canal, and adds that Moro believes it could succeed at Port Said.

Caligny's last note makes exposition of the most essential principles proposed by Moro, and which are to be applied both to drainage and the raising of water by means of waves.

SCREW PROPELLERS.

From "The Engineer."

Mr. Griffiths is well known as the inventor of one of the best, or at all events the most popular, screw propellers ever designed, and this, taken in conjunction with the fact that his experience is considerable and his judgment sound, entitles what he pleases to say on the subject of screw propulsion to much consideration. But Mr. Griffiths, nevertheless, is not infallible, and we fancy that the theory he has recently formed concerning the action of screws—a theory based on elaborate experiments with models—will hardly be accepted as satisfactory by those engineers who have devoted any attention to the propulsion of ships. In brief, Mr. Griffiths' statements go to the effect that by placing one screw in a tunnel near the bows of a ship, and another screw in the ordinary place at the stern, he effects a saving of 50 per cent. in the power required to drive a vessel through the water. This is a very remarkable proposition, involving issues of enormous magnitude, and so far as is apparent from Mr. Griffiths' evidence, it is unquestionably true. Nevertheless, we refuse to accept it as accurate. We hold, on the contrary, that by no new arrangement of screw is it possible to effect a saving of anything like 50 per cent. on the power required to propel a given hull of the best shape through the water, provided care be taken in the first instance to fit her with a normal screw suitable to her requirements. It is possible that the normal single screw used by Mr. Griffiths in his experiments does not at all suit the lines of the model—5 ft. long, 7½ in. beam—to which it is fitted; and before Mr. Griffiths can claim any advantage for his tunnel system, he must show that it was impossible to use a single screw of any shape or pitch from which equally good results could not be got. The model was actuated by spring-driven clockwork; the propelling force was therefore constant under all circumstances, and the efficiency of the propeller was measured by the distance traversed. Now, with twin screws, Mr. Griffiths found that his model ran about 85 ft. in a minute, with 600 revolutions, while with a screw in the tunnel near the bow, and another at the stern, the model ran 95 ft. to 100 ft. in a minute with 600 revolutions. The data, it will be seen here, are incomplete, and cannot be accurately compared, because although the propelling force of the spring driving the clockwork was constant, it is evident that no information is supplied concerning the loss due to friction of the gearing, which, in such small machinery, must be considerable. It is tolerably clear that the loss due to this cause would be greater as regards the twin screws than in the case of the double screws fitted on the new system, because in the latter case both screws might be fixed on the same central shaft, whereas with the twin screws two additional

shafts and two additional wheels would be required. In this respect, to begin with, the whole value of Mr. Griffiths' experiments, in a scientific sense, is neutralized. In order to prove anything concerning the efficiency of the two systems, he must also prove that the force actually expended on the twin screws was identical with that spent on his two screws. It may be said that the error would be but small, and could not produce much effect; but this is contrary to all experience. It is known that with screws an apparently small variation in power will produce very considerable alterations in result; and there should besides be no errors that can possibly be eliminated in experiments such as Mr. Griffiths conducts. To show how easily variations in net power may escape unperceived, we may state that within our own knowledge a large steamer recently gained nearly a knot an hour in speed by being re-engined. The propeller remained the same, and the indicated power of the new engines was practically identical with that of the old engines. These last were very complex and had very short connecting rods. The new engines were very simple and had long connecting rods, and there can be no doubt but that the *indicated* power remaining the same, the *net* power was much greater with the new than it was with the old machinery. There are other reasons, however, why Mr. Griffiths' result should be regarded with extreme caution. That which he proposes to do has, in a sense, been tried over and over again. It may be a new thing to fit a secondary screw in a tunnel running the length of a ship, retaining the original screw; but it is not a new thing to put a screw in a tunnel. Neither is it a good thing. It has been tried repeatedly, and always resulted in failure. Mr. Griffiths must explain how he has obtained results which are totally at variance with those got by every other person who has tried to work screws in tunnels. It is possible that Mr. Griffiths' system has done well, because his tunnel, cut through the length of the ship, permits the accession of plenty of water to the fans of the stern screw. But the fact that the more water a stern screw can get the better, has been known for years; and Mr. Froude showed long since that a remarkable increase in efficiency could be realized by working the screw far astern of the hull, say by extending the propeller shaft to a distance of 20 or 30 ft. behind the rudder. It is obvious, however, that, no matter what advantages might be gained in this way, the expedient is wholly inapplicable to sea-going vessels; and it has yet to be proved that Mr. Griffiths' tunnel could be tolerated in an ocean steamer. That Mr. Griffiths' experiments, as far as they have gone, are interesting we do not dispute, but they require to be extended and verified before they can be accepted as in any mode or form conclusive.

It is not too much to say that no sound or accurate theory of the screw propeller has yet been laid before the world; and the result is that the forms given to propellers by different inventors may be counted by the hundred. The broad principles governing the action of screws, however, may be easily laid down. A ship is caused to move forward because a column of water is made to move astern, and the heavier the column of water the slower its speed astern, and the more directly its line of recession is in the plane of the ship's longitudinal axis, the more efficient will the propeller be. It may be assumed, therefore, that the true work done by either screw or paddles consists in putting a body of water in motion, the forward movement of the hull being simply an accident of that motion; and in designing either screw or paddle-wheels the inventor should concentrate his attention on the water in the first instance as the thing to be moved. Now the paddle-wheel, if well made with feathering floats, can be made to expend a very large proportion of its energy in driving water backwards, especially if made of large diameter, and with very wide and shallow floats. The loss of energy is represented principally by the lifting up water at the back of the wheel, and by the scooping out of a cavity or depression in the liquid beneath the axis. In the case of the screw, however, matters are different. Not only is the screw called upon to drive a large body of water astern, but it also imparts a rotary motion to this column, which, generating—if we may use the word—centrifugal force causes the divergence or spreading of the column; but all the power expended in imparting rotary motion to the column of water is wasted. Let us suppose, for example, that the blades of a screw are flat planes, and that they are twisted round so that these planes are parallel with the keel. It is evident that if caused to revolve, they would offer great

resistance to the engines, and would put large bodies of water in motion, but the hull would remain at rest. Let the blades now be turned at right angles to the keel, and the resistance will be little or nothing; no water will be moved, nor will the ship. If we give the blades an intermediate position we have a screw. One portion of the power is spent in causing rotation of the water, another in driving the water astern. The first is waste, the second is utilized. That screw will, broadly speaking, be the best, that prevents the waste of power by the radial divergence of the water. Various schemes have been tried to effect this end; one, for example, Ericsson's, consisting in placing two screws on the same telescope shaft and causing them to rotate in opposite directions. It is impossible for the first screw, however, to neutralize the effects of the second; and although good results have been obtained from this system, no advantage has been derived which compensates for the complication. Screws have been mounted in tubes to prevent the divergence of the water, but it was forgotten that the water rotates in the tube and escapes from it in rotation, and consequently the moment it quits the tube divergence and loss take place. The scheme has not succeeded. Very recently Dr. Collis Browne has produced a very singular screw—something, in a sense, like the double Mangin screw used in the French navy. The peculiarity lies in the curves given to the blades, which it would be hopeless to attempt to show by an engraving. The intention of the inventor is, however, to gather up the water towards the centre by the first screw, and to throw it right on to the blades of the second screw. Both are fixed on the same shaft, and of course both revolve in the same direction. We believe that the principles involved are now being mathematically investigated, and we understand that Dr. Browne has succeeded in beating every other screw with which his has competed, but enough is not yet known of the propeller to enable us to pronounce any decided opinion on its merits. The truth is that for every form of hull there is a screw better than any other, and this complicates experiments with screws terribly.

Leaving the realms of theory, it will not be out of place to say here that the Hirsch screw appears at present to enjoy a better reputation than any other. At all events, it has been adopted by the Admiralty as the future screw of the British navy—at least till something superior is brought out—and we therefore give a drawing of the screw in its most improved form at page 423. This propeller has now, we understand, been fitted to eighty-six ships, representing an indicated horse-power of 151,374. There appears to be no doubt that this screw is most efficient, and that it secures an almost total absence of vibration. The curves of the blade have been deduced from practice with great care, and on them the good qualities of the propeller apparently depend. It must not be forgotten, however, that difficulties attend us in attempting to estimate the advantages of this as of any other screw. Thus, it will be seen that we have in it four narrow, scimitar-shaped blades. This screw has freqently been tried against two-bladed propellers, which it has beaten; but this is perhaps scarcely a fair comparison. A four-bladed propeller may be better than a two-bladed propeller, and yet very different from the Hirsch screw. However, Mr. Hirsch appears to have obtained a legitimate success, and we shall say nothing which may appear to detract from it in the absence of any facts tending to show that its merits are overrated by shipowners generally and our own Government in particular.

THE APPLICATION OF ACOUSTIC, OPTICAL, ELECTRIC AND MARITIME TELEGRAPHY TO NAVIGATION AND METEOROLOGY.*

By His Excellency Don ARTURO DE MARCOARTU, Ex-Deputy to the Cortes, M. Inst. C. C.

From "The Engineer."

Electric telegraphy commenced by uniting together towns situated in the same State; it afterwards brought bordering nations into communication; further on—and this was the principle of a great revolution—submarine cables crossed straits; and finally, during the last few years, it has ended by enlacing distant continents, islands,

* British Association, Section G.

and coasts in all directions. But, up to the present time, electric telegraphy requires a conducting circuit to unite the two stations; and the prodigies of electricity terminate wherever there is a solution of continuity in the conducting wire. Electric telegraphy cannot go beyond this. For this reason the electric telegraph, which places Great Britain and the United States in complete and permanent communication, is powerless for connecting any of the coasts of these nations with the vessels which are navigating upon the very ocean in whose depths the Anglo-American cables are lying, even when such vessels are but a few miles from the coast.

Acoustic and optical telegraphs (the former hardly ever used at the present day, the latter never), while far more limited in their reach than the electric when the latter can establish its conducting circuit, do not demand this condition for their employ; and hence it is that they may be utilized for the purposes of oceanic telegraphy. An oceanic and atmospheric telegraphic service would require fixed electric stations upon the coast, floating stations provided with electric apparatus for communicating with the coast, and with acoustic and optical apparatus for communicating with the sea; and bodies navigating alike in the ocean as in the air, which, impelled by the waters of the former or by the winds of the latter, are capable of deciphering the measure of the velocity of the oceanic and atmospheric currents. For greater utility in navigation and meteorology, the telegraphic floating stations ought to be established upon capes, in islands, straits, canals, banks, at the mouths of rivers, and in the principal points of passage of commercial movements, and the principal currents of the ocean. The establishment of these floating stations, or moorships, will be more or less difficult, more or less costly, but they will be practicable; and only will be impracticable at but few exceptional points amongst those frequented for purposes of navigation.

It has been asserted that the cannonade of Waterloo could be distinguished at Dover; that that of Carlscrona was heard across the southern extremity of Sweden as far as Denmark, a distance of 120 miles; and that the sound of a sea-fight between the English and Dutch in 1672 was heard across England as far as Shrewsbury, and even in Wales, a distance of 200 miles.

Dr. Arnold relates, that while coming from South America to Europe, and at a distance of 100 leagues from shore, he heard, while standing in the focus of the concave side of one of the sails of the ship, the sound of the bells which were ringing in celebration of a feast at Rio Janeiro. And although these and other circumstances which have been related may not be accepted as indubitable facts, yet authentic experiments have demonstrated the great distance to which sounds are capable of being conveyed through the air, water, snow, or ice.

Their transmission through water is very remarkable. Collandon heard by means of a trumpet submerged on one shore of the Lake of Geneva, the sound of a bell vibrated beneath the water, on the opposite shore, at the distance of 9 miles. I myself heard, a fortnight ago, conversations at Lough Cutra, in Ireland, at a distance impossible were it not for the stillness and evenness of the surface of its waters.

In order to judge of the transmission of sound over the ice, it is enough to remember that Parry relates in the account of his Polar expedition that two men conversed distinctly at a distance of a mile and a quarter. Sounds, after being transmitted through tubes, become wonderfully augmented in volume. Boward states what is correct, that the report of a pistol fired at the mouth of a tube resembles that of a cannon at the other extremity. Jobard placed a watch, the ticking of which was not distinguishable at 30 centimetres distance, in the interior of a tube; and the sound of its movement was then perceptible at a distance of 16 metres. It was the belief of Rumford that the human voice could be rendered audible for a distance of hundreds of leagues by means of tubes. The tubes best adapted for the conveyance of sound are the metallic ones, of copper, iron, zinc, etc.

In order to produce sound at a certain distance it is necessary to originate a direct or indirect shock acting by means of a combination of strings or hammers, or compressed air, or steam, upon vibratory bodies. The force of the motor-agent and the nature of the vibrating body will determine the nature of such sound which is capable of attaining developments not generally employed up to the present time.

For to diversify the volume and tone, besides the nature of the vibrating bodies, the diameter and material of the apertures

of exit can be likewise varied. If it be desired to transmit the sound to considerable distances, it should be collected and made to pass through an acoustic tube; and if upon the emission of the sound it should be desirable to concentrate it in a given direction, in order to increase its compass in such direction, it will be advisable to receive the sound emitted at the extremity of the tubes by means of a paraboloid reflector, the axis of which must be parallel to the desired direction. The variety of volumes and tones producible according to the variety of the vibrating bodies, and the diameters of the orifices giving exit to the sound, and the alternate or intermitting repetitions at longer or shorter intervals of time which may be originated by the combination of the said sounds, will create the elements requisite for the formation of a telegraphic vocabulary.

Three important series of distinctions are capable of being marked by three descriptions of sound only: one of them sharp, as a whistle; another, the sound of a bell; and the third an explosive detonation. Fine weather, for instance, might be indicated by a whistle, which might be made audible for a short period every hour; a bell might give warning of bad weather by means of a scale, according to which, when rung respectively, for the minute with a silent interval of ten minutes; for two minutes with an interval of five; or continuously,—signals of bad weather, progressively becoming worse, might be indicated. The prevailing direction of the winds might be announced by combining the whistle and the bell.

It is easy to perceive that without the necessity of having a person to produce the sound of the whistle and bell, they may be made to vibrate by means of an automotive apparatus of clock-work, which shall place them in communication with a clock every time the weather changes. It will be enough that a clerk should initiate such movements, which would continue until he interrupts them in accordance with the respective atmospheric changes taking place.

From the floating stations, which, on many occasions, should be placed thirty miles, at least, distant from the coast, pneumatic tubes terminating in a floating buoy may be carried out so as to extend several miles further into the sea. These tubes will convey to the buoy the sounds produced by the floating station; and the buoy, with its paraboloid reflector, will direct them seawards. The acoustic tube which unites a land or floating station with a floating buoy, should be metallic, and ought properly to be covered so as to isolate it from the bottom of the sea. Should the tube not be very long, wires might be made to pass through it to operate on the percussion apparatus for producing the sound in the floating buoy; and whether long or short, the tube may always contain a wire conductor of electricity when it may be requisite to produce a detonation with an explosive agent deposited in the floating buoy. The same acoustic tube may on certain occasions be utilized for sending through it to the floating buoy (employing well-known pneumatic principle), latest intelligence in letters, or latest telegrams for steamers at sea; or the boats belonging to the said vessels might place the said latest news in chambers expressly formed in the buoys, and by means of the vacuum produced by a steam engine stationed at the floating or coast station, receive urgent letters or telegrams long before the vessels themselves enter the ports. It does not seem impossible to employ under advantageous economic conditions the force of the sea itself for the service of the tube.

In order that the vessels may be in telegraphic communication with the coast or floating stations, they will have to carry one or more paraboloid reflectors, gyrating round a vertical axis, so as to be placed in any direction of the wind. The whistle and bell will be placed in the focus of these reflectors. A practised observer, when placed within the focus, will hear the signals sent from either land, floating, or navigating stations at several miles distance, and will in his turn cause every other telegraphic station to hear the signals addressed to it.

If two powerful telescopes whose optical axes correspond with each other are fixed, and a light, either solar, reflected, or artificial, be presented before the eye-piece of one of these telescopes, the said light will be distinguished at many miles distance by the other telescope like a brilliant speck. By producing combinations of such a light with eclipses, and varying the time such light is shown and the duration of such eclipses, a telegraphic language might be formed, which, in a clear atmosphere and with a light expressly prepared, would be distinguishable at several miles distance. But when one or both telescopes are in mo-

tion the communication is almost impossible. In this case it becomes necessary to have recourse to reflecting and catadioptric apparatus, as in the lighthouses, and construct a telegraphic vocabulary, by the use of white, green, and red shades, their relative position, their color, and the duration of their respective appearances and eclipses. These optical signals, when made from the coast or floating stations, will be discoverable from vessels, by the aid of telescopes of considerable power, at a distance of several miles. And if vessels were themselves to carry reflecting and catadioptric apparatus they could bring them into operation in case of necessity.

On various occasions bottles have been thrown into the sea for the purpose of observing the path described by them when left to be borne by the currents of the ocean.

It would be very interesting to organize a carefully prepared series of observations, whereby bottles, balloons, and buoys with self-drawing thermometers, containing, besides a note of the geographical point where they have been immersed, notices of the state of the tide, the temperature of the water and of the atmosphere, the intensity and direction of the wind, and other meteorological data of the locality, might, at at the same astronomical hour, be thrown into the sea at different points, say at the equinoxes, solstices, and other seasons of the year. In the same way small aerostatic balloons, conveying useful memoranda of the state of the weather at the place from which they are launched into the lower couch of the atmosphere, might be arranged so as to furnish us with some knowledge of the movements of that couch.

Within the greater portion of the customary maritime routes, which comprehend a zone of thirty miles in breadth, ships might once a week, at least, be placed in communication with the whole world if such ships were supplied with telegraphic apparatus; and there are some routes within which the navigation might be even in daily communication all over the entire globe. Whatever might be the circumstances of the weather, it would be advisable that vessels, although not distinguishable at first sight, should communicate at least at four fixed periods daily. At seven, morning and evening, and twelve noon and midnight, ships might make acoustic and optical signals in all kinds of weather; and in order to observe and receive them severally, it would be proper, for example, that vessels proceeding in directions towards the south and west should make their signals some minutes before the said hours, and that vessels going towards points of the north and east should make theirs some minutes after the same.

At a later period, in 1863, my expectations as to the future of submarine telegraphy were published in a volume printed at New York. After exhibiting the importance which might be rendered by the oceanic telegraph to navigation, my words then were:—

"Every year there are exposed to the dangers of the seas on the Atlantic some 100,000 vessels of 11,000,000 of tons burthen, coastwise and on the high seas, with several millions of souls, passengers and crews, and more than $400,000,000 in value; the annual losses are estimated at from $2,000,000 to $20,000,000. The insurances paid by this amount of shipping during this not long period are more than sufficient to establish a submarine telegraphic net that would give it real security, and free it from maritime disasters. In that day when said submarine net shall unite the coasts and principal islands of the Atlantic, a much easier and cheaper enterprise than it is generally believed to be, and much more humanitarian than it is commonly esteemed—the English, American, French, and Spanish mail packets and vessels, both steam and sailing, of all parts of the world, will find in their ports telegraphic despatches concerning the state of the atmosphere and of the seas which they are about to cross, and into which they now enter, and frequently to meet with certain death. Without being obliged to touch at the telegraph stations, vessels may receive optical signals on the clear seas, or acoustic signals in foggy weather, which would communicate to them (in the same manner in which railroad trains are signalized) the three states of the sea: 'proceed,' 'caution,' 'danger.' The passage of the vessels seen from the stations through powerful telescopes would be announced in telegrams to the many interested and loving ones which the vessels of our day, in all parts of the world, always leave behind them. The want of provisions or the accident to machinery, etc., which so often occur on board vessels, would at once be communicated to the consignees, who would, from their count-

ing-rooms, send such orders as might be best for their interests."

When, then, indicating one of the most noble and humanizing of the future uses of the submarine telegraph, not a few of its readers must have conceived that prophecies founded upon a future event appearing at the moment more doubtful than realizable—the telegraphic union of both worlds—were merely fantastic dreams. The prediction of the weather and aerostation or aerostatic navigation are two problems, the solution of which has been long earnestly sought, and especially at the present time; yet they are both of them alike problems of possible solution under certain and determined conditions, having amongst them certain common relations, and demanding meteorological observations and studies which have been scarcely hitherto initiated.

Arago has absolutely denied the possibility of solving the first, and for the purpose of demonstrating the credulity of the human mind in respect of the marvellous, published the following anecdote, to which Lagrange drew his attention:

"The Academy of Berlin derived formerly its principal revenue from the sale of its almanac. Ashamed at seeing figure in this publication predictions of every kind, made by chance, or which at least were not founded upon any acceptable principle, a distinguished savant proposed to suppress them and to replace them by clear, precise, and definite information upon objects which seemed to him more interesting to the public. The reform was tried, but the income from the almanac was so diminished, and, consequently, the revenues of the Academy were so enfeebled, that it became necessary to retnrn to the former errors, and to give again predictions in which the authors themselves did not believe."

But in spite of the weighty opinion of Arago, it is not difficult to comprehend that the weather, although the result of multifarious, complicated, and at the present day partially unknown forces, is yet in all its vicissitudes produced by specific causes; and that the very same phenomena of weather are reproduced when the intensity, action, and combination of these elements are repeated, and when the same conditions for the elaboration and coincidence of the said forces of nature exist.

We are not called upon to deduce, because our means of observation are at the present day few and imperfect, that it is not possible to discover certain primordial laws which regulate the variations of the weather, especially in the cases of sudden changes and storms, particularly now, when, thanks to telegraphy, the recurrence of a tempest may be known from its very commencement to other parts of the globe, and great catastrophes be thus prevented. Although with very limited resources, and without any organized and effectual co-operation on the part of vessels navigating, the Meteorological Committees of Great Britain, the United States, France, and Germany, have rendered the most important services to navigation and humanity in general by diminishing the number and extent of disasters and misfortunes otherwise inevitable. At the present moment it is far easier to understand how the telegraph may render important assistance to meteorology by announcing the weather prevailing at determined points, under marked conditions, and within certain limits. As soon as it shall have become feasible, over the whole extent of the globe, throughout her seas and continents, to observe simultaneously and at moments which have been pre-arranged, the degree of pressure and hygrometrical condition of the atmosphere; the evaporation which takes place from land and water; the electric state of the air and earth; the velocity, direction, and temperature of the winds and currents; the clouds, rainfalls, inundations, hail and snow-storms, dews and frosts, the earthquakes, and the sanitary condition and movements of epidemics amongst the nations; and when within brief intervals of time the whole system of terrestrial, fluvial, and maritime telegraphs shall interchange this copious stock of details for aiding the study of the laws of nature, it will become possible to predict in a certain measure both atmospheric and maritime changes, and the character and progress of epidemics. Then the difficulties of maritime and aerostatic navigation will be sensibly lessened.

It is a subject for regret that the last North American storm—supposed to have been one of the most terrible ever occurring, and from the consequences of which a dozen Transatlantic packets must have suffered more or less—was not, for want of means for the purpose, adequately observed, so as to have furnished a mass of data of a kind in which we are unfortunately deficient. Ocean telegraphy upon the high seas, limited at the present moment to the almost

primitive system of flag and rocket signals, is destined to make giant strides within the next few years; I shall not be surprised if, by the aid of oceanic and meteorologic telegraphy, a day is at hand when the currents and winds about to be encountered by the mariner will be to him as well known beforehand as the inclines and curves of a line are to the engine driver of a railway train. No cyclone can then engulf a ship by surprise.

I trust I may be permitted to conclude by repeating the hopes I enunciated in a work published at New York, as to the then future of submarine telegraphy now so happily realized.

"The enterprise is both useful and necessary."
"The enterprise, economically and physically speaking, is possible."
"The enterprise will be accomplished."

And in the coming day of the oceanic telegraphy, we may repeat the following words of Psalm xix.:—

"3. There is no speech nor language,
where their voice is not heard."
"4. Their line is gone out throughout all the earth,
and their words to the end of the world."

POLLUTION OF RIVERS, AND ITS PREVENTION.

From "Iron."

The vast increase which has taken place during the last few years in the mining and manufacturing industries of Great Britain has far outstripped all the precautions that the Legislature has at any time enacted should be taken to prevent the fouling of the rivers of the country, by the pouring into them of the refuse incidental to manufactures of all kinds. But at no time have we, or our ancestors, been sufficiently jealous of the purity of our streams. Pure water is the prime necessity of man's existence. He wants it for his own use, to drink and to wash in; he wants it for his cattle; he wants it for his crops; water is the great natural purifier of the air; pure water is necessary to the existence of fish; in fact, without water there can be no life. Whatever legislative enactments have been made, have been passed, not with a view to the general sanitary condition of the country, but with some special and perhaps minor object; and no general law on the subject is in existence. The Thames has its special Conservancy Act, but the other rivers are left comparatively unprotected.

When Acts have been passed, such as the Act of 1862, for preventing the pollution of the Mersey and Irwell, they are practically inoperative; in other cases the measures adopted are curative, not preventive. Instead, for instance, of preventing the passing of solid refuse into rivers, large sums of money are annually spent in dredging, in order to preserve the requisite depth of water in our navigable rivers. Other Acts, again, have actually tended to this evil. The Alkali Act, passed in 1862, with the view of preventing the escape of noxious vapors into the atmosphere, has resulted in the discharge of the gases, in a condensed, solid state, into the rivers.

The Water Works Act (10 & 11 Vict., c. 17) enacts (secs. 61–65) that no stream, reservoir, or aqueduct, belonging to waterworks or reservoir companies, shall be polluted in any way, under a penalty of £5, and £1 for each day during which the offence is continued. Owners of gasworks permitting any foul liquid or solid matter to flow into such waters are subjected to a fine of £200, and £20 a day during the continuance of the offence. The Nuisances Removal (Scotland) Act of 1856 (19 & 20 Vict., c. 103, sec. 19) prohibits the placing of gas, naphtha, vitriol, or dyestuffs, or their refuse, into waters, under a penalty of £50 for every such offence and £5 a day during its continuance. The Malicious Injuries Act (24 & 25 Vict., c. 97, sec. 32) and the various Salmon Fisheries Acts of England, Scotland, and Ireland, contain clauses against the pollution of rivers, which were especially framed in the interests of the fish and their proprietors. But these Acts are not sufficiently comprehensive to prevent the nuisance they were intended to abate. Their provisions in some cases can be easily evaded, and the machinery for carrying them out is not sufficient. But, even then, many rivers would continue to be polluted which would not come under their special care, and a comprehensive general law on the subject is absolutely necessary.

The inspectors and commissioners of salmon fisheries, and the local boards of

conservators, throughout the kingdom, do considerable good in their endeavors to abate the nuisances caused by the pollution of our rivers, but where they succeed in their efforts their success is but as a flea-bite on the enormous masses of pollution, liquid and solid, that are being daily poured into our rivers. They do better work in making the public aware of the injury that is inflicted by the, in many cases, preventable and frequently wasteful flow of various pollutions into the streams. The following catalogue of various causes of pollution, reported by these officials as existing almost unchecked in different parts of the kingdom, will give some idea of the dangers we are incurring and the waste that is taking place. In Scotland, Messrs. Buckland and Young, in a report on the salmon fisheries of that country, enumerate the following pollutions as occurring:—Chloride of lime from paper mills; bleach works' refuse; paraffine; naphtha; town sewage; dye-works' refuse; distilleries' refuse; sawdust; coal-pit water; mine water; factory refuse; lint steeping; sheep washing; starch works' refuse; tanyard refuse; and many others.

In Ireland the water from flax works may be added to the above list, whilst in England and Wales the sources of pollution are innumerable. China clay works, tin plate works, chemical works, "hush" of the deadliest character from mines of all kinds, quarries, oil works, print works, in addition to the above-named sources of pollution, add their quota to the general work of destruction. There is hardly a pure river in the country, and the Conway may be said to be the only stream that has not seriously suffered.

Some rivers are actually named from the appearance they present in consequence of the pollutions that are poured into them. The Redbrook, in South Wales, is red with the refuse from the plate works; the Blackburn and Devil's water in Northumberland, are as black with coal washings as ever water so named could be imagined. The Whitebrook, a tributary of the Wye, is white with the refuse chloride of lime from a paper mill.

Any one travelling in the manufacturing or mining districts cannot help noticing the thick discolored streams of poisoned mud, miscalled rivers, which, but for these frightful pollutions, would be pure limpid brooks, abounding with life and producing a supply of clear drinking water. We do not need the reports that are daily published of the destruction not only of vegetation, fish, birds, and animals, but even human beings, by polluted water, to know that this state of things ought not to be. The rivers were never intended to be turned into sewers, and it is the duty of every one to consider the public good, the general health and welfare of the country, before the minor questions of personal benefit; and manufacturers and mine owners—all who deal with noxious matters—should use every endeavor to utilize such matters, or, at any rate, to nullify their evil effects before they go the length of pouring them into the rivers.

The Royal Commission on the pollution of rivers has been taking evidence on this subject for several years past, with the object of legislating on this question; but they have not yet finished their inquiries, and their useful recommendations for diverting pollutions from rivers remain ignored. But the question has become too pressing for further delay, and a Bill was introduced last session into the House of Lords, with stringent enactments for carrying out this much-needed reform. Penalties were proposed upon "every person who places or throws, or causes to be placed, thrown, or to fall, or knowingly or negligently permits to be placed, thrown, or to fall into any river the solid refuse of any manufactory, or any rubbish, cinders, sawdust, or any other solid matter or substance whatsoever, to such an extent as either to interfere with the flow of or to pollute such river," or, who "opens into any river any sewer, drain, pipe, or channel, with intent or in order thereby to provide for the flow or passage of sewage, or of any other offensive or injurious matter; causes or without lawful excuse (the proof whereof shall lie on the person accused) suffers any sewage or any foul, offensive, injurious matter to flow or pass into any river through any sewer, drain, pipe, or channel not at the passing of this Act used for that purpose." Filthy or noxious water or other liquid or washings of any trade, business, process, or manufactories, or any polluting liquid, it is proposed should be forbidden to be carried into rivers.

Of course a standard of purity is necessary in legislation of this kind, and accordingly the following was incorporated in the Bill as a definition of polluting liquids,

based upon the recommendations of the Rivers Pollution Commission:—

(1) Any liquids "containing in suspension more than three parts by weight of dry mineral matter, or one part by weight of dry organic matter, in 100,000 parts by weight of the liquid; (2) containing in solution more than two parts by weight of organic carbon, or three parts by weight of organic nitrogen, in 100,000 parts by weight of the liquid; (3) which exhibits by daylight a distinct color when a stratum of 1 in. deep is placed in a white porcelain or earthenware vessel; (4) which contains in solution in 100,000 parts by weight more than two parts by weight of any metal, except calcium, magnesium, potassium, and sodium; (5) which in 10,000 by weight contains, whether in solution or suspension, in chemical combination or otherwise, more than .05 part by weight of metallic arsenic; (6) which, after acidification with sulphuric acid, contains in 100,000 parts by weight more than one part by weight of free chlorine; (7) which contains in 100,000 parts by weight more than one part by weight of sulphur in the condition either of sulphuretted hydrogen or a soluble sulphuret; (8) possessing an acidity greater than that which is produced by adding two parts by weight of real muriatic acid to 1,000 parts by weight of distilled water; (9) possessing an alkalinity greater than that produced by adding one part by weight of dry caustic soda to 1,000 parts by weight of distilled water; (10) exhibiting a film of petroleum or hydrocarbon oil upon its surface, or containing in suspension in 100,000 parts more than .05 part of such oil."

The Local Government Board was to have power to alter the definitions of a polluting liquid as described above, and to diminish or increase their stringency as they may think necessary. The penalties are not to apply where the pollution was caused by excessive rainfall or discharge of storm water, or where the best practicable means have been adopted for its prevention. Notice is to be given of the time at which any pollution is to be discontinued. This time can be extended by the pollution authority if it is found to be necessary or desirable.

The Bill, though it passed a Second Reading in the Lords, was unfortunately too late to become law last session; but we have given the above details of its provisions, as we understand that it is to be introduced in essentially the same shape next year.

We trust that, in the interest of every member of the community, this Bill may become law; and we shall now endeavor to show that it will be to the advantage of manufacturers themselves to dispose of their refuse matter in some other way than pouring it, just as it leaves their hands, without any attempt at purification, into the rivers. We hope that they will not offer a factious opposition to a measure of so universally beneficial a nature, on the plea that the attempt to deal with pollutions will stand in the way of the full development of their manufactures, and impede commercial enterprise. On the contrary, in many cases, a new impulse will be given to commercial enterprise, and new industries will be developed, while the more indirect gain that they will derive from the purer state of the rivers will, in all cases, repay any outlay that may be occasioned. The Bill was prepared under the auspices of the Fisheries Preservation Association, of which the Duke of Northumberland is President; and is supported by a society headed by Lord Polwarth, which has been instituted in Edinburgh for the express purpose of taking measures to remove impurities from our rivers.

The report of the first meeting of the Rivers Purification Association, as this society is named, has lately been published, and gives as concise a summary as has ever been issued of the various processes in actual use for the treatment of one great source of pollution—viz., sewage. Hitherto sewage has been the chief enemy that has been attacked; and we observe, in looking through the report, that all the remedies of which sketches are given are mainly intended as means whereby this particular nuisance shall be kept out of the rivers and turned to advantage. Descriptions of no less than eleven systems of dealing with sewage, with their special advantages and shortcomings, are given. The names of such men as Mr. Wm. Hope, Mr. Baldwin Latham, Mr. Bailey Denton, Dr. Anderson, Mr. McLagan, M. P., are sufficient to show that the knowledge and experience of thoroughly practical men will be brought to bear on the good work which the committee appointed by the Association have set themselves to do. Some of the papers and reports read give most interesting statistics as to the various systems now in use—

systems at present existing more as models and specimens than as actual and accomplished successes. One gentleman waxed poetical on the question of dry earth-closets, quoting from Shakespeare, Scott, Prior, and Milton in support of his system; but it is not in isolated processes that ultimate success will be found; rather, as Mr. Baldwin Latham said, "a combined system will probably be that which will be adopted by towns." He was speaking purely of sewage; but the other and greater evils from the above-mentioned sources must not be neglected.

It is not necessary here to enter into the sewage question; every one acknowledges nowadays that the proper place for the sewage is the land, not the water. The question is, how shall the principle be carried out? Irrigationists and precipitationists may fight over the bone if they will. It has already been satisfactorily shown that the sewage can be profitably utilized, so we need not step in and discriminate between the respective merits of the various systems. It is our task, rather, to point out means by which other and more serious modes of pollution may be profitably utilized, to the actual pecuniary benefit of those who will only adopt those means.

The most serious kinds of pollution are those containing chemical solutions, which can only be treated by a chemical process neutralizing or extracting the poison, otherwise there is hardly any kind of liquid refuse that cannot be purified by filtration or subsidence. The refuse water from dye works, print works, and bleach works can be so purified by filtration, when in the foulest possible state, that it may be turned without offence into the river. The experiments of the Royal Commission on Rivers Pollution show that arsenic is removed from such waste liquors by filtration. How great would be the individual gain of manufacturers if, instead of having to depend on water companies for a supply of water at a large annual outlay, they were to adopt this plan of purifying their water before turning it into the river, whence all of them would then be able to derive an unfailing supply of pure water without cost. If the manufacturer at the head of the stream were to set the example, and his neighbors below would follow it, the river would be passed on from each to the other in a pure state, instead of in so foul a condition that the lowest manufactories are unable to use it.

But in the case of mines, the benefits to be derived from such a course are more apparent. The simple use of settling-pits, in which the mine-water is allowed to rest till the solid impurities subside, is sufficient to remove all the solid matters, so that the effluent water may be safely poured into the river. The mud or slime thus separated should be removed every day, and may be profitably utilized in the following manner, described by Mr. Frank Buckland:—"As regards the debris and mud of crushed rock, I am happy to say that some economical use can be made of it. I am informed by Mr. George, superintendent of the Upper Severn, that in the Van mines the slime from the catch-pits is being made into bricks, by being mixed with sand and burnt. They make very good bricks, and are used on the premises. This idea is most valuable, and all lead mine owners should adopt it. I have myself made several bricks with debris of lead mines and Portland cement; Roman cement will do. I shall be glad to send samples of these bricks to any person who applies for them. I have been informed by the foreman of the new works at the Old Windsor Lock on the Thames that the cement which sets best under water is Burham Company cement. The proportions for water work are one cement to four of washed gravel or refuse from lead mines; for other work one cement to eight or ten of washed gravel or lead refuse; this composition sets like solid rock." Not only can bricks be made of mud, but in some cases a considerable quantity of ore may be saved from it, which would otherwise be wasted.

The solid matters in the washings from China clay works, which do so much injury to the rivers of Devonshire and Cornwall, as well as the debris from mines, can be utilized by making bricks. But when the refuse cannot be made use of, it is desirable that "catch-pits," or settling-pits, should be made to receive the waste water from all such works. The Pollution Commissioners testify that settling-pits are capable of extracting in some cases a portion even of chemical impurities, but the solid matters can be easily removed by this means at no expense. The proper way is to have a double series of pits or tanks, large enough to hold a day's wash-water, so that the washings from one day can be subsiding in

one set while the other set is being filled. This plan is most simple, and very efficacious.

The Devon Great Consolidated Mining Company employ the following simple plan for the extraction of copper in solution in waste mine-water, with most excellent results: The water is first passed through large filtering beds, to divest it of all earthy matter, and then conveyed over scrap-iron in a series of strips sufficient to throw the whole of the copper down. The iron is turned over and brushed during the day by a man in charge, to prevent it from becoming too thickly coated with copper when it would cease to be acted on. The copper is caught in a catch-pit at the end of each watercourse. The iron displaced by the action of the acid passes off in the form of ochre, which is caught in pits prepared for the purpose, and the water is again finally passed through a series of catch-pits and ponds before passing into the river.

The refuse from the tanyards is a fruitful source of pollution, but there is no reason why the rivers should receive this matter, which, if applied to the land, is a valuable manure. Why such a simple use for the waste water as turning it on the land as manure should so often remain ignored, we are puzzled to explain. The waste waters from other factories can also be utilized in this way after undergoing some simple processes. The dye-water from dye works can be purified in a very simple manner, and the refuse, after pouring off the clean water, used as manure. This liquor is, in its ordinary state, one of the most polluting of liquids, but it can be clarified by simple filtration through ashes or by precipitation. This latter process is hastened by the addition of lime. The dye-water is a solution of sulphate of iron, with insoluble dye matter in suspension. It should be turned into subsiding pits or tanks, when, on the addition of a little lime, the coloring matter is at once precipitated, and the superincumbent water is left clear. The proportion of lime is 10 lbs. to 1,000 gallons of water. By this means the water can be drained off comparatively pure and colorless, insted of going to foul the river and unfit its waters for use by manufacturers and others below.

Another mode of dealing with the refuse water from dye and print works is thus described by the Rivers Pollution Commission: "A form of mechanical filter, which has been found very valuable in several manufactures, early attracted our attention. It is a patent invention, known as Needham's press, consisting of a number of narrow chambers, lined with linen or calico, into which the liquid to be filtered is driven by a small force-pump. The liquid passes clear through the bags, while the solid portions are arrested. This action is maintained with low pressure until the chambers begin to be filled with solid residue, when it is necessary to increase the pressure. The machine is extensively used in the Potteries for the separation of clay from water in which it has been washed; it is also successfully adopted in paper-making, in breweries, and some other manufactures. The thin mixture of clay and water, known as 'slip,' was formerly dried on hot plates till it became fit for working. In many potteries the mixture is now pumped into Needham's machine under great pressure, and when the operation is complete the clay is taken out in solid cakes, which are strong enough to be readily handled and fit for the use of the potter.

"By the kindness of Mr. Henry Brooke, and under the superintendence and at the expense of Mr. Needham, one of these presses was fitted up in the dry-house at Bradley Mills, near Huddersfield, and experiments were made from day to day in the filtration of black dye. These trials were very satisfactory to us, as showing that it is perfectly practicable to separate from the dye-waste the most objectionable portion, and to discharge into the rivers a liquid comparatively pure. The machine actually employed at Bradley Mills, although only about 7 ft. square by 3 ft. in height, had a filtering area of 240 ft., and by it we were enabled to cleanse 700 to 1000 gallons of limed black dye-waste in an hour. The tank in which the dye-water was precipitated was capable of holding from 2,500 to 3,000 gallons, and was calculated for the treatment of from one to two days' discharge. Mr. Brooke considered that this tank and machine would enable him to purify all the dye refuse produced at his mill before discharge into the river. With regard to the solid material which is found in the cloths when the machine is taken to pieces, this substance is, as has been already explained, a combination of oxide of iron and vegetable matter. It is not difficult to dispose of it when taken from the press. It is similar to damp sawdust, and may be got rid of by

mixing it with small coal, and burning it under the furnaces; better still is it to allow the material to dry up (which, from its light porous nature it readily does), and then to set fire to it; it burns like a slow match without flame, but so persistently that a heap once alight will burn till all the vegetable matter is consumed. There remains, after combustion, a red powder which is almost entirely oxide of iron. It forms from one-fifth to a quarter the weight of the black stuff, and would undoubtedly find a market, either to be made into red or chocolate paint for external ironwork, or to be used in the purification of gas, or for conversion into perchloride of iron for purposes of deodorization."

Waste water fron dye and print works, of all colors, may be treated in a similar way, and we feel assured that if a prohibition were at once to be placed on the pouring of such matters into our rivers, the ingenuity of our manufacturers would easily find some simple means of getting rid of it without injury, if not with direct profit to themselves.

STORAGE AND DISTRIBUTION OF WATER IN INDIA.*

By GEORGE GORDON, M. Inst. C. E.

It is not intended in this paper to discuss the value of water in its widest sense, or to consider the indirect benefits which would follow the control and abundant distribution of the enormous wealth of water now, for the most part, rolled into the sea—benefits among which are to be reckoned the prevention of famines and of scarcity in the districts concerned, as well as the permanent improvement of agriculture, and the numberless social and political advantages resulting from enhanced prosperity and increase of population. The object of this communication is rather to afford, from well-authenticated data, some means of estimating the more direct profits of works of irrigation which have been, or could be undertaken as commercial speculations in the present day. For this purpose some preliminary remarks on the works employed for storage and distribution, on the ancient and modern systems, seem needful.

TANK IRRIGATION.

The existing tank irrigation dates chiefly from ancient times. The number of tanks, large and small, in Southern India is enormous; some of them attain the dimensions of lakes, others suffice only for the irrigation of a few acres. They may be divided into three classes: 1st. Where advantage is taken of a narrow gorge in a range of hills, to close the passage of a river, by a dam or embankment of considerable height, and so to convert the valley above into a lake. 2d. Tanks formed by the construction of embankments across one or more streams in the flat country, this class being often of considerable superficial extent, but comparatively shallow. 3d. Such as may be considered intermediate between the first and second classes.

Most of the tanks of the first class are now ruined. In many cases the earthen embankment has been breached, in consequence of the water finding a passage along the outside of the discharge culvert, which was generally placed under the embankment, and not in a tunnel at a distance. The dams were, it is believed, invariably made of earth, without any puddle core, and the inner slope was always protected with heavy stone pitching.

The Author is not aware that high masonry dams were ever constructed for storage purposes in Southern India; but there is, near Ahmednuggur, in the Bombay Presidency, an instance of the combined use of masonry and earth, in a dam for a large ancient tank, described by Colonel Fife, R. E., in the Roorkee Papers. This dam, however, was never finished.

The number of disused tanks, of all sizes, is very remarkable. Many of these are not breached, but the discharge culvert is left open, and no water is collected. In many cases this is, probably, owing to the bed of the tank having been gradually raised by silting, and converted into so productive a soil, that it yields as much as, or more than, could be obtained by means of the diminished quantity of water applied to the comparatively barren soil below the tank; but generally it results from the ascertained fact, that the rainfall in some districts has

* Abstract from the Minutes of the Proceedings of the Institution of Civil Engineers.

materially diminished (markedly so even within the memory of man), on which account the tanks would never fill, and in most years would receive so small, and especially so uncertain a supply, as to render wet cultivation to any large extent not to be depended on. Dozens of such abandoned tanks are met with in the hilly parts of the Ceded Districts; as, for instance, along the foot of the inner slope of the Eastern Ghats, where, in many cases, both the bed of the tank and the cultivated land below it have reverted to jungle.

A good specimen of the tanks of the first kind is one which the Author was deputed to examine a few years ago, with a view to its restoration. A short description of it will afford an idea, both of the construction of ancient works and of the untrustworthy nature of the data which old works seem to afford for the construction of new works.

The Mudduk Masoor Tank is believed to have been constructed under the Annagoondy dynasty, about four centuries ago. It was formed by an embankment, resting on the sides of a narrow gorge through which the river Choardy passed, supplemented by two bunds, or dams, on saddles in the range of hills; that on the east being 1,350 yards, and that on the west 670 yards from the main bund. The length of the main bund is 550 yards on the top. The inside slope, of $2\frac{1}{2}$ to 1, in some parts 3 to 1, was revetted with large stones, up to a cubic yard in bulk. It is from 945 to 1,100 ft. broad at the base, and is now from 91 to 108 ft. high. There was a sluice under the dam at the east end about the level of the ground. The dam is composed of a strong red earth, with a considerable admixture of gravel, taken from the sides of the hills on which it rests. The east supplemental bund has its base 74 ft. above the sluice in the main bund, and had also a sluice under it at the ground level. The west supplemental bund, the breaching of which destroyed the tank, seems to have been of similar construction to the others, and its base was perhaps 50 or 60 ft. above the bed of the tank. There is no trace of any waste-weir, and it is probable that the want of this was the cause of the ruin of the tank. On the main bund there are what seem to be traces of the water having topped it, and having cut into the rear slope in two deep gullies. The west bund had, probably, a sluice in it which weakened it, as cut stones were found in the river some way down. After this bund was breached, the water cut into the ground on which it stood to the depth of 100 ft., and would have completely emptied the tank but for a reef of rock some distance from the dam, on the inner side, which now causes a waterfall 25 to 30 ft. in height, and retains about 10 ft. of water in the tank. On this reef a weir has been built.

From the heights of the dams and the levels of the sluices, it is probable that the depth of the tank was 90 or 95 ft., and at that level its area would have been 40 square miles, and its contents about 1,400 million cubic yards of water. The drainage basin is about 500 square miles, and three-fourths of it lies within the jungly district containing the spurs of the Western Ghats. It is found, from observations of the discharge of the river, that a good average monsoon supply would not exceed 668,000,000 cubic yards, or 16 in. running off. It is not probable that the average annual rainfall so near the Western Ghats has diminished much, although it may, to some extent, from land having been cleared of jungle; nor is there anything to show that the ancient tank filled every year. The difference between the present supply, and what it must be supposed to have been when the tank filled and was breached (even supposing that to have occurred in an exceptional year), is probably owing, in part, to the construction of small tanks on some of the feeders. The tank, as proposed to be restored, would have contained about 644,000,000 cubic yards; and the results are given subsequently. As regards capacity, this is the largest reservoir in Southern India of which the Author can find any record.

Flat-country Tanks are so numerous in some districts that, looking at a map, it would appear as if as much land is occupied by tanks as is left to be irrigated by them; and where the tanks are very shallow, this would be necessary for complete irrigation. But in reality, many of these tanks are breached or abandoned, and their beds cultivated. The embankments of flat-country tanks are often of great length, not unusually 1 mile or 2 miles, while that of the Veeranum tank is 12 miles, and the ruined bank of the Poonairy tank, in the Trichinopoly district, is said to be 30 miles in length. Their height is generally inconsiderable, being, in many hundreds of cases, only sufficient to hold 10 ft., or even 6 ft. of

water. Some works, however, of this, or of the intermediate class already mentioned, are (or were) 20, 40, and even 60 ft. deep. The inner side is generally revetted with stone, and has a slope sometimes of 1 to 1, but oftener of 2 to 1, or more. In some cases it is a masonry wall backed with earth. Clay puddle is not used in forming the banks, but the best earth in the immediate neighborhood is employed, and the dimensions are made large and sometimes excessive. The height above the water-level varies; for instance, the Nundyal tank bund is, at one place, 18 ft. high, 2 ft. above the water-level, 16 ft. wide on the top, with an inside slope of 1 to 1 and an outside slope of $2\frac{1}{2}$ to 1. The Kolevoy tank in the Nellore district has a bank 36 ft. high, 9 ft. above the water-level, a top width of 12 ft., and slopes, inside and outside, of $1\frac{1}{2}$ to 1.

Of Tanks of the Third, or Intermediate Class, the Darojee tank, in the Bellary district, is a good example. The embankment is about 2 miles in length, and rests on two rocky hills, two small hillocks being also included in the line of the bank. The area, when full, is about $2\frac{1}{4}$ square miles. Its height is about 40 ft., the depth of water being 26 ft. at the level of the waste-weir. This is of modern construction, and 400 ft. long, the old native one having been breached. The contents of this tank are roughly estimated at 25,000,000 cubic yards.

As the smaller streams in Southern India are merely torrents which quickly carry off heavy falls of rain and then become dry again, their powers of supply being reckoned by hours at a time rather than by weeks or months, they are, if utilized for irrigation at all, in most cases intercepted by chains of tanks of the second or third class built across their course. Therefore it is only the more important rivers that can supply means of extensive irrigation by channels diverted from them, and it is believed that all of these rivers were, to some extent, laid under contribution in former times.

Naturally their deltas formed the best ground for irrigation, and, consequently, the Godavery and the Kristna deltas, and the lands in the lower parts of the course of the Pennair, Palar, Cauvery, etc., have been, to a large extent, irrigated for ages, and the works have been much extended and improved by the British Government. It is chiefly from these exceptionally favored districts that the wonderful—and in some cases almost incredible—results of channel irrigation have been obtained. As descriptions of many of these works are accessible to the members, it seems unnecessary to occupy time in giving any account of them in this Paper, further than to say that, with one important exception, the conditions under which they were constructed are as favorable as they could be, viz., ground sloping moderately towards the sea and from the river—the source of supply, so that distribution of the water commences almost immediately; the absence of deep or hard cuttings in the canals; and, in the case of the modern improvements, the presence of a considerable population accustomed to the construction of such works and alive to the advantage of their extension. The one disadvantage referred to is the difficulty of constructing and maintaining weirs across the wide sandy beds of the rivers. This was beyond the skill of the native constructors. Very interesting accounts of some of these works will be found in the Professional Papers of the Madras Engineers, and in the Government records in the Library of the Institution.

But it is not only in the deltas that the rivers are tapped. In the middle reaches of the large rivers also there are many ancient weirs, generally admirably situated, but of rude and imperfect construction, so that many are ruined and others require extensive annual repairs. Advantage was usually taken of a reef of rocks running across the river, the low places being filled in with rubble, faced on both sides with large blocks of stone laid dry, occasionally fastened together. There is some leakage through the body of these native weirs, but not sufficient to account for the fact that, although they are not provided with scouring sluices, the bed of the river on the upper side of them has in several cases not been raised, as is the case where weirs have lately been built with scouring sluices at one end or both.

Where new weirs have been built on rock, they are generally of masonry, with a vertical or slightly battering face on the lower side. It is frequently necessary to protect the rock from the action of the falling water by a water cushion, formed by a low wall built a short way below the weir. The Author has seen a block weighing several tons picked out of what seemed, before the weir was built, a solid bed of gneiss with no visible seams; the height to

the crest of the weir was, speaking from memory, not more then 7 ft., and there may have been 5 or 6 ft. going over the crest. The Author knows of no rule for determining the depth of the water cushion, by the height of the fall and the volume of the water. The greatest depth of the hole formed by the water-fall in the new outlet of the Mudduk Masoor tank is 24 ft. At the low state of the river, the height of the lip of the fall is 27½ ft. above the surface of the water below. In ordinary states of the river, the general depth of the cushion, or well, is to the height of the fall as 3 to 4 where the greatest action takes place, and 1 to 2 in the other places. At the Gairsoppa Falls, in the Western Ghats, the Rajah fall, which through its whole height falls clear of the rock, is 825 ft. high, and the pool into which it falls is 138 ft. deep in the low state of the river. Perhaps 8 ft. on the edge of the fall would be the depth in floods, and then the surface of the cauldron below, if it could be said to have one, would be raised many feet; it would be impossible to measure it. An experimental fall on the Baree Doab canal had a height of 6.9 ft., depth of well 9 ft., and 3.6 ft. on the crest, which gives the depth of the well to the height of the fall as 3 to 4; and it is said the water had no injurious effect on the bottom of the well, and that a bottle, loaded so as to be of the same specific gravity as the water, and passed over the fall, did not reach the bottom by a foot and a half.

In sandy-bedded rivers, the modern practice is to build the weir on a foundation of wells filled with concrete, to give it an apron sloping about 1 in 12 from the crest, with a toe wall, and if the slope is long, one or more intermediate walls, also built on wells, and below all a broad layer of rough rubble of large dimensions. A good example of this kind is the Madras Irrigation Company's weir across the Pennair, near Cuddapah, of which a description will will be given to the Institution by Mr. Higginson, M. Inst. C. E.

All the ancient irrigation channels from above weirs, that have come under the Author's notice, have far too great a fall, and consequently cannot get away from the river, and thus only a narrow strip of land is irrigated; the sides and bed of the channel get cut away in some places, and the material deposited in others, so that annual repairs and clearing out are necessary. There is also invariably a great waste of water in distribution; but as the surplus runs into the river it is not lost, being picked up again at the next weir. The tail of one channel generally overlaps the head of the next for some distance in the native system. There can be little doubt that this system of numerous weirs and small channels, with a rapid fall, is radically wrong, when applied to large rivers for extensive irrigation. On smaller rivers, having a steep fall, say of 10 ft. or more per mile, rocky beds, and widths so moderate as to make the cost of the weir a small part of the whole work, it may sometimes be well applied—the more so as in such situations the soil is likely to be of a light and porous nature, requiring a large quantity of water to be spread over it, and delivering the surplus by drainage into the river again. Generally speaking, however, in the case of large rivers it will be found more economical to take off a canal of larger dimensions from one head. The surface fall of the water can then be much less than in a channel the depth of which is small; the canal will rapidly recede from the river bank, and command, compared to its length, a much larger area of land; it will wind less, as it will cross the drainage valleys higher up, where they are less deep; these drainages will require less expensive aqueducts and approaches; there will be a shorter length of unproductive canal at the head (from the off-take to where the canal level is high enough to deliver water on to the surface of the ground), and it will supply water to lands and villages where it is more urgently needed than it is close along the banks of a river. Careful estimates, however, are needed, in each case, of considerations on the other side. For instance, the canal must not be made of so large a capacity that a great part of the water must be carried very many miles before it can be used. The cost of distribution, too, must be considered. Although the natural channels of streams can often be used to convey part of the water to the fields, it is generally the case that, for extensive irrigation, artificial channels, carried down the ridges crossed by the canal, are more economical; but they must not be too long.

It is desirable that a main canal should command a much greater area of arable land than the water it carries can irrigate constantly. Some land may not be suitable

for irrigation at all; and in no case could all the land be converted from dry to wet cultivation under many years, as three times the population would be required to cultivate it. There should, therefore, be facilities for completely irrigating detached areas at considerable intervals, and for giving occasional irrigation to dry crops. This last would be an immense boon, since in many parts complete failure of the crops now grown happens every few years from drought, and a good crop is a rare exception; while from one to three waterings would insure a good crop every year. A failure of the crop means a famine; and although, in the few districts traversed by railways, food and seed grain for next year could, at a great cost, be provided for the people, fodder, and, above all water for the cattle, could not, and they must be driven away or perish. At one large military station, so great was the scarcity of water in the early part of the year 1871, that arrangements were actually completed for carrying water a distance of 8 miles on railway-trucks for the use of the inhabitants. As to drink water thus provided would be contrary to the religious obligations of caste-men, their dismay was great. Fortunately, a heavy rain furnished a supply for two or three months.

The large storage tanks already described as of the first class do not have more than a limited area of land irrigated immediately from them. Their duty is to store flood-water which would otherwise run to waste, and to let it down the river as it is required, to supplement, if necessary, at the end of the season, the regular monsoon supply for the first crop, or to give a supply for a second, and to be distributed either by channel irrigation from the river, or from the flat-country tanks, if it is used to supply them. From the second and third class of tanks the distribution is generally effected directly, beginning close under the tank, the water being let out on to the land by sluices at different levels. In some cases, however, as in that of the Darojee tank already mentioned, the water is also carried down the beds of the intercepted streams and picked up by weirs put across them at intervals; but this is the less frequent plan. One advantage of it is, that the drainage and also the superfluous water from the fields, for it is always wastefully used, are not lost.

Distribution from a canal is most economically effected when the latter runs along a ridge between two valleys, so that it can supply water on both sides; for the nearer the irrigated land lies to the supply the less do the distribution channels cost. This situation, in the case of a large canal taken from one of the main drainages of the country, can obviously happen only in rare instances. When the main canal is carried along sidelong ground crossing the drainage of the country, the main irrigating channels will generally be carried down the ridges between the streams, giving off secondary branches right and left. Occasionally, when the main canal passes by a cutting through a ridge crossing its course, a channel on a falling contour will be required on the upper, and another on the lower slope of such ridge, uniting when the crest of the ridge falls to their level. The first kind, or ridge channels, have the advantage of crossing no drainage, of being thus less liable to damage from heavy rains, and of commanding a given area with the least length of side channels. In most cases both kind of channels will be needed. In the Ceded Districts, distribution can be carried out for 5s. per acre, including the sluices in the main canal bank, and all necessary works for crossing roads and streams built in a permanent manner, but excluding the cost of terracing the land to prepare it for wet cultivation,—this being done by the occupier.

Of course, any system of irrigation must include ample means of drainage. This is afforded naturally in the part of India under consideration, the fall of the country being generally steeper than is necessary. Only surface drainage is practised. For rice cultivation the water must not be carried off too rapidly, but should be retained for months at a depth of 6 in. on the surface of the ground, by surrounding the plots with a small bank, through which a slight stream is allowed to pass on and off. For dry crops the ground never holds too much rain; the more careful cultivators endeavor to retain, by small dams of dry rubble or boulders, the finer parts of the soil, which would otherwise be carried of by the very heavy rains; but, except in irrigated lands, drains are never cut, as far as the Author is aware.*

* Only so much of Mr. Gordon's paper is produced here as seemed to contain valuable suggestions to American Engineers. At this point detailed estimates of cost and of values for Indian crops are omitted.

GENERAL CONCLUSIONS.

As there seems to exist a general impression, that the estimates of the benefits of irrigation are merely estimates, more or less colored by personal views, the author has, in the statements of the comparative results of wet and dry cultivation, confined himself to ascertained facts, and has endeavored to keep the estimates of returns on works within the limits of certainty by excluding all doubtful or unascertainable profits, such as those from plantations for firewood (a very profitable investment where the earth can be kept sufficiently moist), water supplied to towns and villages for domestic and municipal purposes, water-power, etc. Also, he has taken as the standard of productiveness that of irrigation under tanks, and has not added the 25 per cent. additional crop said to be due to channel irrigation.

As this paper is intended to deal with works for irrigation only, navigation is not included in either the cost or the returns; but the Author begs leave to make one or two remarks on this subject, on which so much opposition exists in the views of engineers. This opposition he believes arises from each side attempting to form general conclusions, and to lay down a general rule founded on the observation of particular works, which in each case seem to bear out its advocate's views. The question does not admit of a general answer, either in favor of or adverse to the combination of irrigation and of navigation in one channel. Assuming that a navigable canal is desirable, if it can be constructed at a small outlay, the question whether an irrigation canal should be adapted to that use or not seems to depend for its solution mainly on two circumstances: first, the nature of the ground through which it passes; and, secondly, on its dimensions. If the former is such that a rapid current can be given to the water, it is very desirable to do so in cuttings, in order to reduce their cross section, and this generally to such an extent as would prevent upward navigation. If, on the other hand, the country is very level, as in deltas, and the soil so light that the velocity of the canal has to be small, then the addition of works required for navigation bears so small a proportion to the whole outlay, that to make the irrigation canal navigable is the cheapest way of attaining the end. Thus, in the Orissa scheme, the cost of the navigation works is said to be about one-eighth of the whole cost; and a complete network of navigable lines is obtained at an outlay of £650 per mile. In a less easy country the Author has found that when a canal has to carry from 150,000 to 500,000 cubic yards per hour, and when it has to pass through cuttings, it would be cheaper to have a separate navigation taken round, or in some other way avoiding the difficult parts, than so to enlarge the irrigation canal as to reduce its current within navigable limits. But when a canal has tapered down to 150,000 or 100,000 cubic yards per hour, then it is cheaper to combine irrigation with navigation in one canal. In a tract of country comprising both characters of ground, it was found that to combine a system of navigation with irrigation would add 25 per cent. to the cost of the latter, and would cost from £2,000 to £3,000 per mile, according to the dimensions of the work; but in difficult ground, if the canal were of large dimensions, carrying 450,000 cubic yards per hour, £6,000 per mile would be required to make it navigable. The parts of the canal used for navigation only would cost £1,200 or £1,500 per mile, exclusive of the locks, which, if 100 ft. long and 20 ft. wide, would cost about £200 per foot of lift. These rates per mile suppose a supply derived from the canal, and do not include headworks or storage reservoirs, as these works are supposed to be charged to irrigation, inasmuch as the water used for lockage would also be expended in the fields.

In the above estimates no account has been taken of the value of the land occupied by the works. It has generally a low value in such districts as require irrigation. In the Orissa system of works it cost 1.8 per cent. of the capital expended; and in any case it becomes quite insignificant, when compared with the indirect advantages accruing to Government from the improvement of the country by irrigation. The most obvious of these is the saving of remissions of land revenue, which have often to be made in consequence of partial or total failure of crops. There is also the relief from uncertainty in the amount of the revenue. In the irrigated districts of Tanjore, the fluctuations in the revenue have declined since the construction of the Government irrigation works from 52 per cent. to 3 or 4 per cent. Other sources of gain to the State are—waste lands brought under cultivation, and so under a charge

for rent; increase of the customs and taxation in general; and a large saving of money relief in times of famine. These gains cannot be estimated, and no account has been taken of them in the above calculations, except as a set off against the value of the land.

No special notice has been taken in this Paper of the great and very remunerative works in the Kristna, Godavery, and Tanjore deltas, the works in the last yielding, according to an independent authority, after deducting repairs and 5 per cent. on the capital, 23½ per cent. direct profits, and those on the Godavery from 50 to 60 per cent. They are omitted because these deltas are so occupied as to offer no opportunity of constructing new works on a large scale.

Persons unacquainted with the native character will be apt to ask why, if irrigation works are so profitable, the natives have not already utilized every drop of available water; but this will be no ground of wonder to those who know their ignorance of the practice of any but their own neighborhood, their worship of custom, and their habit of relying on their rulers to do everything for them. In the Godavery districts, on the completion of the works, the Government officers are said to have acted in a paternal manner to the ryots by turning the water on to their fields, with or without their consent, and they have been rewarded by the unexampled prosperity of the district.

The object of this Paper will have been attained if it has shown:

First.—That all works of irrigation benefit the cultivator to such an extent as will enable him to pay a water-rate equal to two-thirds of the increased value of his crop, and not exceeding one-half the net value, and still to leave his own profits by 100 to 400 per cent. in excess of those derived from dry cultivation.

Secondly.—The storage of water for the raising of a second crop, under distribution works already in existence, is the most profitable, and would, after paying one-third of the gross revenue to the existing works, still yield a net return of 46 per cent. on the outlay, and increase the revenue of the existing works, supposing them to have cost the average sum, by 4¼ per cent.

Thirdly.—That the arbitrary rate of 12s. per acre is insufficient, on the data assumed by the Government, to yield a fair return directly on the average of new irrigation works, unless these include the storage of water, when the Government rate will yield a net profit, on storage and distribution works combined, of 10 per cent.

And *Fourthly.*—That as a consequence of the last, the profitable employment of unguaranteed capital in irrigation works depends chiefly on the recognition of the principle, that the water-rate should be fixed with reference to the value of the crop produced. This value will, in all probability, continue to increase, as will also the cost of the works as wages increase; and unless the water-rate is fixed with due regard to the value of the water to the consumers, and to the cost of work in each district, many beneficial projects will remain unexecuted.

(To be continued.)

THEORY OF THE GIFFARD INJECTOR.

Translated from "Sonnet's Dictionnaire des Mathematiques Appliquées."

To establish the complete and rigorous theory of this apparatus would be very difficult. Mr. Giffard in his "Notice Théorique de l'Injecteur Automatique" (1861), has given an approximate theory founded upon the doctrine of the conservation of the *quantity of motion.*

Let p = the weight of the liquid which escapes in one second from the orifice of the tuyere.
P = the weight of water moved by suction.
m and M = the corresponding masses.
ω the section of the orifice of the tuyere.
V = the velocity of the steam at this point.
v = the velocity of the water at this point.
a = the minimum section ($m\ m$) of the divergent tube.

Let us consider the portion of fluid in motion between two sections near the end of the spindle, and near the small end of the diverging tube. At the end of a very short time θ the molecules which were in one section will be transferred to the other. Because of the conservation of motion the quantity of motion of the portion of fluid comprised between the sections will be constant; hence the increase of the quantity

of motion of the fluid between the above specified sections is reduced to

$$(m+\mathrm{M})\,\theta\,v - m\,\theta\,\mathrm{V}.$$

Let R be the sum of the projections upon the axis of motion of the exterior forces acting on the fluid; then by virtue of the principle of the quantity of motion

$$(m+\mathrm{M})\,\theta\,v - m\,\theta\,\mathrm{V} = \mathrm{R}\,\theta$$

or

$$(m+\mathrm{M})\,v - m\,\mathrm{V} = \mathrm{R}.$$

Neglecting friction, and assuming that the resultants of the pressures in the two directions are equal, R = 0, and

$$(m+\mathrm{M})\,v - m\,\mathrm{V} = 0,$$

or, substituting weights for masses

$$(\mathrm{P}+p)\,v - p\,\mathrm{V} = 0 \quad . \quad . \quad (1.)$$

$$\therefore p = (\mathrm{P}+p)\frac{v}{\mathrm{V}} \quad . \quad . \quad (2.)$$

The sum $\mathrm{P}+p$ is generally given; it is the weight of the water to be introduced into the boiler in a second of time; and it is equal to the weight of steam to be generated by the boiler according to its heating surface, increased by about 40 to 100 per cent. in order to take into account the water mechanically moved. The velocities v and V are not directly given. Mr. Giffard considers that the fluid escapes with the same density. Let δ represent this density, or rather the weight of a cubic metre of steam, and n the number of atmospheres pressure in the boiler, diminished by unity; since the pressure about the fluid vein may be regarded as equal to the atmospheric pressure: then

$$\mathrm{V} = \sqrt{2\,g\frac{10334\,n}{\delta}} \qquad (3.)$$

Let W = the weight of a cubic metre of the liquid flowing into the divergent tube. In order that this may be introduced into the boiler, the *vis viva* must be equal to the negative work of the pressure, which opposes this introduction; *i. e.*

$$v = \sqrt{2\,g\,\mathrm{H}}$$

H being the height of fluid to which the pressure is due. But experience shows that at the mouth of the divergent tube the liquid, still mingled with air and steam not condensed, has a density much less than that of water; on the other hand, in taking into account the friction in the divergent tube, it is necessary to give the liquid an excess of velocity. In view of this, Giffard proposes the following formula

$$\mathrm{V} = \sqrt{2\,g\,k\frac{10334\,n}{1000}} \quad . \quad . \quad (4.)$$

k being a coefficient between 2 and 2.25, as determined by experiment.

Further, we have

$$p = \omega\,\mathrm{V}\,d \quad . \quad . \quad . \quad (5.)$$

and

$$\mathrm{P}+p = a\,v\,\mathrm{W}.$$

W being the weight of a cubic metre of liquid in the divergent tube, *i. e.*, about 500 kil. Formulas (2), (3), (4), (5), (6), contain the solution of the problem.

Equations (3) and (4) give the velocities V and v; (2) determines the weight p; (5) and (6) give the sections ω and a.

The temperature of the feed water is easily derived from the values of P and p. Let T represent the temperature of the steam at departure from the feed pipe and τ that of the mixture which flows into the divergent tube. The quantity of heat lost by the steam in passing from the temperature T to τ is according to Regnault

$$p\,(606.5 + 0.305\,\mathrm{T} - t)$$

and the quantity of heat gained by the water passing from the temperature t to τ is $\mathrm{P}\,(\tau - t)$.

The loss being equal to the gain,

$$p\,(606.5 + 0.305\,\mathrm{T} - \tau) = \mathrm{P}\,(\tau - t)$$

$$\therefore \tau = \frac{p\,(606.5 + 0.305\,\mathrm{T}) + p\,t}{\mathrm{P}+p}$$

The temperature T is not exactly known; but we may suppose it equal at least to 100°; and from it we can hence deduce the minimum of temperature of mixture.

Suppose, for example, a boiler in which the steam is generated at a pressure of 6 atm., with a heated surface of 20 c. m. Allowing a mean generation of 20 k. of steam per square metre hourly, we have a product of 400 k. Add about 40 per cent. for water set in motion, and we have 560 k. per hour, or 0.155555 c. m. per second. In this case

$$\mathrm{P}+p = 0.156 \text{ kil.}$$

nearly

$$n = 5$$

Density at 6 atm. (160°.2) = 0.003

$\therefore \delta$ = weight of cubic metre = 3 kil.

Hence

$$V = \sqrt{2g \cdot \frac{10334.5}{3}} = 581.3 \text{ m.}$$

$$v = \sqrt{2g \cdot 2.25 \frac{10334.5}{1000}} = 47.8 \text{ m.}$$

Hence

$$p = 0.156 \times \frac{47.8}{581.3} = 0.0128 \text{ k.}$$

Formulas (5) and (6) give

$$\omega = 7.34 \text{ sq. met.}$$
$$a = 6.53 \text{ sq. met.}$$

Corresponding to diameters of 3 and 2.5 mm.

Supposing the water in the reservoir at 12° and T = 100°.

$$\tau = 12° + 0.082\,(637 - 12) = 63°.25,$$

the minimum of temperature for feed water.

NEW MODE OF HARDENING STEEL AND REGENERATION OF BURNT IRON.

By Lieutenant-Colonel H. CARON.

From "Iron."

A piece of steel is first hardened, then softened more or less, according to the hardness or elasticity desired. The hardening, as it is ordinarily practised, that is to say, the hardening of the red-hot metal in cold water, frequently has the grave inconvenience of developing rents and cracks disadvantageous to the powers of resistance of the metal. The process of softening then gone through does not cause these defects to disappear; later, in the using, these fissures, invisible at first, increase little by little, and finally end in a serious rupture. It is already well known that to obviate in part such a danger, it is better to make the steel less hard, and soften it more lightly. A spring heated red-hot, hardened in cold water and softened with burning oil, possesses the same elasticity as a similar spring hardened with cold oil (a weaker hardening than the first) and softened with "smoking" oil (a lesser softening than the preceding); only the latter method is more advantageous, because there is less fear of cracks from a too rapid cooling of the metal. Wishing to go farther, I asked myself if it were really necessary to commence by hardening the steel beyond measure, just to reverse the process and soften it by a second operation. With this in view I have sought a hardening of such mildness as to remove as much as possible the chances of cracks, and produce in the steel, at a single operation, the effects of hardening and softening combined.

I have found a very simple method, namely, by warming the water into which the red-hot metal is to be thrown. After ome experiments a temperature of about 5 deg. was found to be sufficient to give to the above-mentioned springs (springs of needle-guns) an elasticity and resistance equal to that produced by the best hardened followed by an after softening. Necessarily the temperature must vary with the size of the piece and the uses to which it is destined. The degree of warmth of the bath is easy to determine by trying it beforehand.

Hardening with very hot water, and better still, boiling, singularly modifies soft steel containing .002 to .004 of carbon. It increases its tenacity and elasticity without materially altering its softness; the grain changes in nature, and often where there is a breach it is found to have become fibrous instead of granular or crystalline, as it was before.

In a communication inserted in the Report of the Academy of Science last year, I have demonstrated that the crystalline texture presented by the fracture of certain pieces of iron is neither due to the action of the cold nor to that of prolonged vibration, but that it existed in the metal previous to its being used. After my experience, that particular formation I found to result from an incomplete forging, leaving the metal still "burnt," *i. e.*, crystalline and full of cracks. I said, besides, that it was possible to give the iron thus deteriorated the fibrous texture or the tenacity which it would have had if the operations of the forge had been well gone through, and that, without having recourse, as was formerly done, to a new hammering, which results in a loss of time, of metal, and often in the wasting of the piece itself. The means which I employ to regenerate burn-iron is like that of hardening red-hot metal

in warm water. I shall cite but one example to prove this.

A bar of Berry iron, three centimetres in diameter, easy to break, without a crack, cleft, or flaw, was burnt, *i. e.*, warmed in such a manner that, pressed in a screw-vice, it could be broken without bending. The fracture was strewn with brilliant facets of many thousand squares. A boiling liquid, strongly impregnated with ordinary salt, was prepared; a piece of the burnt iron, heated red-hot, was plunged in this liquid, during the time necessary to bring the metal to the temperature of the bath (about 110 deg.). It immediately produced a rather curious phenomenon; directly it was plunged in the salt solution the red metal was covered with white salt, which detached it from the water, and certainly contributed to diminish its cooling. The piece of iron thus hardened was capable of being bent back upon itself, as the bar had been before being burnt. Pure water, boiling, can be employed as well, but its effects are less marked.

Now it is known that boiling salt-water can regenerate burnt iron, it will be to the interest of the manufacturer to apply this operation to pieces after being finished at the forge, as the hardening will not damage them at all; if, on the contrary, they have suffered from too much or too prolonged heat, it will give them the qualities which a good forging imparts. Just the same applies to steel.

It is likely that there may be other liquids and other solutions which would produce the same results as the saline solution, but I have only mentioned this one because it appears to me to be the most economical and the most easily procured at the same time.

REPORTS OF ENGINEERS' SOCIETIES.

American Society of Civil Engineers.—At the evening meeting of the Society to be held Wednesday, January 21st, "Test of materials used in construction, and testing machines" will be considered; reference is made to the Report of the Committee on "Tests of American iron and steel," and the remarks offered at the meeting held November 17th last, herewith published; members having information upon the subject are requested to present it; full descriptions of testing machines in use are specially asked for.

At the evening meeting of the Society to be held Wednesday, February 18th, an examination into "The elements of cost of railroad traffic" will be made, with a view to determine the same under their appropriate heads, and to discover wherein, and in what manner, a reduction may be effected. The discussion upon LXII Transactions, herewith published, bears upon this subject, which it is hoped railroad managers and others interested will take up and continue. Details of the several items of cost of railroad traffic, as given in reports or otherwise, and references to where such may be found, are desired.

IRON AND STEEL NOTES.

Improvement in Hardening the Surfaces of Iron. — Specification forming part of Letters Patent issued to Robert T. King, of Pana, Ill.

The object of this invention is to furnish a suitable compound for case-hardening iron, or converting the surface into steel; and it consists in a combination of various ingredients or substances, which form the composition hereinafter mentioned, and used in about the proportions named, for forming the compound, viz.: Lamp-black, sixteen parts; sal-soda, eight parts; muriate of soda, four parts; black oxide of manganese, one part.

These substances are combined in the above proportions (by weight), and are finely powdered.

The iron is heated in any suitable forge or furnace, and, having been wrought into the shape of the implement or article to be used, and the surface thereof prepared by grinding, the compound is applied by sprinkling or sifting, or by immersing the iron therein. The effect is to carbonize and steelify the surface of the iron to a greater or less extent.

A thinner or thicker scale of steel is formed by varying the quantity of the compound applied or the temperature of the iron to be case-hardened.

Claim.—The above described compound, substantially as and for the purposes herein shown and described.—*Iron Age.*

Improvement in Welding Iron and Steel.—Specification forming part of Letters Patent issued to Joseph Popping, of New York.

This invention is in the nature of an improvement in the process of welding iron and steel; and the invention consists in applying between the surfaces to be welded a compound of borax, iron filings, and prussiate of potassa, and subjecting the iron to a red heat and pressure or percussion, and thereby welding the same.

As is well known, in welding iron it has been necessary to heat the pieces to be welded together to a white heat, and that while this process of welding answers for welding iron, it does not, without great care and danger of destroying the steel, answer for welding steel to steel or steel to iron, for the reason that the white heat required does, in many instances, destroy the steel. Hence, more or less difficulty has always attended the welding of iron and steel together.

By this invention iron is welded to steel and iron to iron without difficulty. The surface of the metal it is designed to weld is moistened with water, and on the wet surface is sprinkled a compound consisting of 1 lb. of pulverized calcined

borax, 1 lb. of fine iron filings, and 4 oz. of pulverized prussiate of potassa, intimately mixed together, the moistened surfaces of the iron causing the above compound to adhere to them. The two surfaces to be welded are then placed together and wired, or otherwise held in place, and put into a fire and brought up to a red heat, or to a temperature of 600 or 700 deg. Fahrenheit. The red-hot metal may then be passed between rolls or placed under a hammer, when the rolling or hammering will complete the process, forming a strong and perfect weld, the welded surfaces being intimately blended together. The prussiate of potassa may be calcined, which will facilitate the welding to some extent. The proportionate amount of the above ingredients may be varied more or less without particularly affecting the result.

Claim.—1. For welding purposes, a compound composed of calcined borax, iron filings, and prussiate of potassa, in the proportions, and applied in the manner, hereinbefore described.

2. The process, hereinbefore described, of welding iron and steel, viz., applying to the surfaces to be welded the compound named, joining the prepared surfaces of the metal together, heating them red-hot, and hammering or rolling the same.—*Iron Age.*

RAILWAY NOTES.

A NOVEL LOCOMOTIVE.—There has just been completed at the machine-shop of Lafferty & Bros., Gloucester City, N. J., a four-ton locomotive, designed to run on one rail. It is built for a street railroad company in Georgia. This engine can with propriety be called a steam velocipede, as it rests upon two wheels, one following the other. The rail or track upon which it is to run, a sample of which is laid in the yard of the builders, is styled "Prismoid, or one track railway," and is composed of several thicknesses of plank, built up in the style of an inverted keel of a vessel, with a flat rail on the apex. Upon a trial a speed of about twelve miles an hour was attained, and the inventor and patentee claims that the speed can be almost doubled on a lengthened track. Mr. E. Crew, of Opelika, Ga., is the inventor and patentee of both tracks and engines, and he claims that his invention demonstrates a tractive power superior to anything in the locomotive line of equal weight. The capacity for running curves is very much greater than the tow-rail system. The track upon which the trial was made contained 36 ft. of lumber and 18 lbs. of iron to the lineal foot, proving itself equal to a span of 20 ft., remaining firm and unyielding under the pressure of the engine as it traversed the road. The revolving flanges attached to the engine, and which run on the outside of each wheel, Mr. Crew claims, absolutely lock the rolling stock to the prism, and obviate the necessity of so much heavy rolling stock in light traffic at a high rate of speed. It is also claimed that a prismoidal railway built with a base of fourteen inches, angles forty degrees, can be built at a cost of $3,000 per mile. The inventor is of opinion that this engine and track is particularly adapted to the propelling of canal boats, and will compete sucessfully with horse-power on canals without necessarily interfering with the use of the latter, but he does not state in what way. The engine will shortly be shipped to its destination (Atlanta, Ga.), where it goes into operation on a street railroad, built at an elevation of twelve feet above the sidewalk.—*Am. Manufacturer.*

THE WORK OF 1873.—We give elsewhere an elaborate statement of the work done in constructing new railroads in 1873, which is, we believe, very nearly exact. We have attempted to describe in it the length and location of every railroad and part of a railroad constructed during the year with sufficient exactness to enable the reader to draw it roughly on the map.

STATE.	New road in		Per cent. of increase in 1873.	Total at close of 1873.
	1872.	1873.		
Alabama	134	0	0	1,566
Arkansas	156	247½	55	697
California	195	85	7	1,305
Colorado	105	121	25	604
Connecticut	25	29	3½	897
Dakota	210	80½	37	291
Delaware	26½	21½	8¾	275
Florida	10½	0	0	466
Georgia	46	99	4⅜	2,259
Illinois	686½	253½	4	6,615
Indiana	183	65	1¾	3,714
Indian Territory	149	0	0	279
Iowa	452	93	2⅜	3,736
Kansas	445	36	1⅜	2,377
Kentucky	143	54	4¼	1,320
Louisiana	3	0	0	539
Maine	62½	0	0	871
Massachusetts	37	113½	7	1,772
Maryland and D. C.	190	34	3½	1,046
Michigan	571	182	6½	3,071
Minnesota	307	43⅜	2¾	1,950
Mississippi	22	7	0⅝	997
Missouri	314	236⅜	9	2,910
Nebraska	212	0	0	1,051
Nevada	18	18	3	629
New Hampshire	43	48	7⅝	858
New Jersey	103	40⅜	3	1,418
New York	435	242	5	5,417
North Carolina	60	15	1¼	1,265
Ohio	456½	131	3½	4,239
Oregon	82	10	4	251
Pennsylvania	251	191	3⅜	5,560
Rhode Island	0	22	16	158
South Carolina	88	88	6⅔	1,378
Tennessee	15	114	7½	1,634
Texas	391	485½	45	1,563
Utah	57	85	24	434
Vermont	31	53	7⅛	763
Virginia	49¾	36	2½	1,573
Washington	40	40	60	105
West Virginia	76	36	6¾	597
Wisconsin	459½	320½	17	2,198
Wyoming	0	0	0	459
Totals and average..	7,340	3,777	5	70,857

There are many things which will be more apparent from the tabular statement given above than from the more elaborate account of the sepa-

rate lines. This table gives the mileage of railroad completed in 1872 as well as in 1873, the percentage of increase of the last year, and the total at the close of the year. As authority for the mileage at the close of 1872 we have taken "Poor's Manual," which may be not always correct, but is doubtless the best statement we have. We have never made an attempt to ascertain exactly the mileage of each State existing at any given date, and therefore are unwilling to be responsible for the total mileage given.

The contrast between the first and second columns in this table is very striking, and especially in their totals. We built very little more than half as much railroad in 1873 as in 1872, and while the rate of increase for the whole country was 12¼ per cent. in 1872 it was only 5 per cent. last year. It should not be forgotten, however, that this is itself a very large increase. It makes the total completed in the United States since 1865 just about 35,800 miles, or more than half of the entire mileage of the country at this date was constructed within the last eight years.

The progress in the different States has been various, of course. Ten of them show a greater mileage than last year, including all the New England States except Maine, which is one of the seven States and Territories which have no new mileage, besides the four (Arizona, New Mexico, Montana and Idaho) which never have had any.

In the order of the amount of new road constructed in the year, those which have built more than 100 miles rank as follows: Texas, Wisconsin, Illinois, Arkansas, New York, Missouri, Pennsylvania, Michigan, Ohio, Colorado, Tennessee and Massachusetts. There are 265 miles of new railroad in New England, 595 in the old four "Middle States," 272 in the Southern Atlantic Coast States, from Maryland to Florida inclusive, only seven miles in all the Gulf States east of Texas, 733 in Texas and Arkansas (which may be called the West of the South, and almost its only new country), 168 miles in Tennessee and Kentucky, 995 in the six Western States which touch the great lakes, from Ohio to Minnesota, 446 in the States and Territories north of Arkansas west of the Mississippi and east of the Rockies (excluding Minnesota), 225 in the mountain Territories and States east of California, and 135 on the Pacific coast.

Texas, Arkansas, and Wisconsin have made really notable progress during the year, increasing by a very large percentage as well as a large mileage the railroad within their borders.

The decline of railroad construction began with the beginning, not the close, of the year. It was perhaps the first decided sympton of the financial difficulties which overwhelmed the country in September. An examination of our record will show that an unusually large part of the new work consisted in the *completion* of roads previously begun, and that, comparatively, not many of the new lines will need to be extended before they can be made available, though doubtless many of them require considerable expenditures to put them in anything like good order for traffic. Our rule regarding reporting the construction of a new road is to give it *when the rails are laid.* When this has been done the road is pretty sure to be worked for traffic.

As to the prospects for the current year, 1874, we have given our opinion frequently that there is likely to be a still smaller construction of *new lines.* Our railroads depend almost exclusively upon borrowed money—that is, scarcely any of them can be completed without *some* borrowed money—and investors are likely to be very slow for some time to come to lend money on the security of incomplete lines not yet earning any income. There is, however, a great need of extensive new works on old lines; these are likely to have good credit, and they may to a considerable extent make up for the decline in the building of new railroads.—*Railroad Gazette.*

ENGINEERING STRUCTURES.

BRIDGES IN FRANCE.—According to some recent statistics published by the Minister of Public Works, it appears that there are at the present time 1,982 bridges of importance in France, 861 of which were built previous to the nineteenth century, 64 during the First Empire, 180 during the Restoration, 580 in the reign of Louis Philippe, and 297 since 1848. With regard to the material of which they are constructed, 854 are of stone, 9 iron, 70 suspension bridges, 67 with masonry piers and wooden superstructures, 14 entirely of timber, and 20 of wood, iron, and masonry combined. 1,067 of these bridges are on national roads, 18 on roads for strategical purposes, 6 on fresh roads, and 891 on Departmental roads. Among the most important are the bridge of Bordeaux, commenced under the First Empire, 501 metres in length, consisting of 17 arches, and cost 6,850,000f.; the suspension bridge over the Dordogne at Cubzac, 545 metres in length, cost 2,200,000f.; the "Saint Esprit" bridge over the Rhone, commenced in 1265, consisting of 18 arches, is 738 metres in length, and cost not less than 4,500,000 francs; the bridge at Toulouse over the Garonne, cost 2,700,000f.; that at Libourne on the Dordogne, 4,236,948f.; the bridge at Tours over the Loire, 125 metres in length, consisting of 15 arches, cost 4,224,639f.; the "Pont de la Guillotine" over the Rhone at Lyons, commenced in 1245 with 8 arches, and 263 metres long, is estimated to have cost 2½ milliards; the Penfield swing bridge at Brest was constructed at a cost of 2,800,000f.; the Pont Neuf over the Seine at Paris, commenced in 1578, 231 metres in length, cost 4,000,000 francs; the Pont d'Jena, also at Paris, built under the First Empire at a cost of 6,135,105f.; the Pont de Roane, 232 metres in length, commenced in 1811, cost 6,438,561f. The total length of these bridges is estimated by the engineers of the "Ponts et Chausees" to be about 166 kilometres (about 100 English miles), and the cost of their construction 286,507,761f. (£11,460,310.)—*Building News.*

NEW HYDRAULIC BRIDGE AT LEITH.—The new hydraulic bridge connecting the Victoria and Albert Docks, and spanning the harbor near the Prince of Wales Graving Dock, Leith, has been tried swung. Some idea may be formed of the power of the hydraulic machine fitted up by Sir William Armstrong, when it is stated that the bridge is 214 ft. long, 39 ft. broad, and weighs 600 tons, and that the machine easily moved the ponderous bridge on its pivot. This trial was

made merely for the satisfaction of the engineers and other persons interested; but before the Harbor and Dock Commissioners take the bridge off the contractors' hands a more formal testing of the machinery will take place. A double line of rails have been laid on the bridge, and the railway lines connected with the Caledonian and North British systems in North and South Leith will be brought to the bridge as soon as it is thoroughly complete. The centre of the bridge will be appropriated to railway and carriage traffic, and on each side will be convenient footpaths for pedestrians. It is expected that the contractors will complete the whole of the works in a few weeks.—*Iron.*

PROPOSAL FOR A THIRD ALPINE TUNNEL.—Italy appears to derive more benefit from the prevailing passion among engineers for great works than any other country. To those fond of tunnel-making her Alps afford the most brilliant field of activity. She already has the Mont Cenis tunnel, that of Saint Gothard is under way, and now it is proposed to pierce grand old St. Bernard by a passage way 5,800 metres (about 6,380 yards long). It is proposed, says "Iron," to construct this tunnel in four sections, by means of side galleries, so that the work may be completed in three or four years. These working galleries will remain open afterwards for ventilation and other uses. A peculiar feature is that it is proposed to form a station within this tunnel by widening 600 metres of the level, central portion; one of the objects which has led to this singular plan is, that possibly for economy's sake two light trains which had made the ascent separately might be joined together for the descent on the other side. It is also argued that with such an arrangement many tourists would be glad in the summer season to attain the summits of the group of the Grand St. Bernard by the inclined passages already referred to, and at the mouths of which stations for refreshment, and even for lodging, might be established. The cost of this part of the work is estimated at only 17,000,000 francs; but to make the great tunnel of use, a railroad will have to be built through a most difficult country requiring several other tunnels of less size; so that the cost of the whole work is put (in advance) at 90,000,000 francs, or close on $18,000,000, gold.

AQUA DA VERRUGAS.—A correspondent of the New York "Times" describes this structure (built by the Baltimore Bridge Co.), on the line of the Callao & Oroya R., Peru, as one of the finest engineering works in existence,—remarkable as the highest of the kind in the world, and for surpassing all others of the same class in its perfect system of bracing and connections. The viaduct crosses a wild and picturesque ravine, through which foams and flashes a small mountain torrent. It consists of four deck spans (Fink truss), three of which are 110 ft. long, and one, the central, 125 ft. The spans rest on piers built of wrought-iron columns, and these piers are 50 ft. long by 15 ft. wide on top. There being three piers, the total length of the viaduct is 575 ft. These piers are the great feature of interest, and are, respectively, 145, 252, and 187 ft. high. Each consists of 12 legs (in a rectange), composed of a series of wrought-iron six-segment columns, in lengths of 25 ft., connections being made by cast-iron joint-boxes, having tenons on each end running into the column. The tenons and the face of the casting against which the column bears are machine dressed, so as to face. The columns have an exterior diameter of 12 in., and a diameter, including flanges, of 16 in. The legs of the piers are securely fastened together by three systems of brace-rods running transversely, longitudinally and laterally, and braced by longitudinal and transverse iron shutes. These braces and shutes are connected at the joints by bolts and small pins. Transversely, the pin has the shape of an inverted W, two legs batter in and two out, the outer having a batter of 1 ft. in 12, and the inner so inclined as to make the above-mentioned shape. There are three of these W's in a pier, each containing four legs, making 12 in all. The piers were raised within themselves, tier upon tier, the material being drawn up by a common windlass. The side spans were raised with the usual scaffolding, but the central span, having been put together on a staging a few feet above the ground, was lifted bodily 250 ft. This method is said to be quicker and more economical than any other, as a single span of masonry would have cost twice as much, and not been so safe.

HOOSAC TUNNEL VENTILATION.—The theory that the tunnel would be ventilated without the aid of the central shaft is, says the Springfield "Republican," practically established. Mr. Shanly recently passed through, and reports a fine breeze from east to west through the entire length, which, as, the week before, the current was strong from west to east, fully confirms the belief that nature will attend to the ventilation, without the aid of artificial chimneys. There will be a little dripping of water at short distances at several points. This would not injure trains any more than a light shower; but, to prevent injury to bed, there will be erected over the wet portions roofs of galvanized iron to carry the water off to the gutters on the sides of the track.

THE dissection of continents by inter-oceanic canals, seems to be one of the principal tendencies of the day. The latest aspirant for the somewhat doubtful financial honors of such an undertaking is Mr. Theodore Tubini, banker of Athens, Greece, who has obtained a concession for a canal through the Isthmus of Corinth. The prism of the canal is to be 8¼ metres (28⅛ ft.) deep and 12 metres (40 ft.) wide at bottom. At the centre will be a dock covering about 37,000 sq. yards. This work is to be finished in six years, and will cost four million dollars. Our own canal, through the Isthmus of Darien, is by no means laid on the shelf, and the advantages it offers to this country in particular, but also to all others, are a strong ground for expecting a steady effort to carry out the work. Three routes have been surveyed, one across the Isthmus of Darien proper, one by the Isthmus of Tehuantepec, and the third by Lake Nicaragua. The second of these lines may be left out of consideration, partly on account of the high elevation to be surmounted, and partly because the water supply is not certain for all the levels. By either of the other routes the cost would be $60,000,000 or thereabouts. At Darien the highest level is 120 ft.

above the sea, and a tunnel three miles long would be needed. Against these advantages are to be placed the existence of good natural harbors and the shortness of the canal. By the Nicaragua route tunnelling would be avoided, the height of lockage is only 103 ft., and the summit level is formed by an inland sea 35 miles wide. This would undoubtedly offer decided advantages as a quiet harbor for repairs, etc., and for transhipment of freight. Ships from California would also save nearly a thousand miles over the Darien route. These different routes, with the reports of the surveying parties who have examined them, are under consideration by General Humphreys, Chief of U. S. Engineers, and Prof. Pierce of the Coast Survey, and these gentlemen will make a recommendation to Congress on the subject.—*Engineering and Mining Journal.*

ORDNANCE AND NAVAL.

A COPPER-CLAD SHIP FOR CARRYING COMBUSTIBLE FREIGHT.—The importation of corrosive sublimate, vitriol, and similar dangerous compounds has heretofore been carried on to a small extent, says the Jersey City "Journal," owing to the damages ensuing to the ships used in their transportation, as the leakage and draining from the different named substances, when mixed in the bilge water of the vessels, has, in most instances, eaten the bottoms out of the vessels.

A company in England running to the East Indies first thought of using copper in the construction of their vessels as a preventive against the bugs that infest that locality, the said bugs being considered death to all wooden vessels, and instances have been shown of the successful depredations of the insects even on iron-clad ships. To obviate these drawbacks to commerce, a ship was built completely encased in copper.

The frame-work is of iron, which, however, is not exposed in the least. The outside is covered with sheets of thick copper, riveted in the same manner as the iron vessels. The whole interior of the ship is also made of copper, the inside copper being galvanized, the beams, and, in fact, every exposed part being completely protected by copper; the masts are of wood, but sheathed in copper from top to stem. The name of this copper monster is the Adirondack; she is a screw steamer, and is capable of carrying 7,000 tons, Custom House measurement, and is about 515 feet in length, being some seventy feet longer than any of the Oceanic Company's ships.

The White Star line have purchased this steamship for the purpose of carrying such freight as mentioned. Her upper deck has been fitted up with a large tank for carrying oil of vitriol in bulk, lunar caustic, potash, sal soda, and, in fact, all similar kinds of freight will be imported in larger quantities now, should the trial trip succeed, which there is every prospect of its doing. The Adirondack is now being got ready for her trip, and will arrive in this port in the course of a fortnight. She is coated on her outside with a preparation of fat and copal varnish, to protect her from the effects of sea water, and it is said that the reflection of the ship upon the ocean on a bright sunny day is like the reflection of the sun at sunset on a large building containing many windows, only on a larger scale. It is claimed that she can be seen at sea on such a day a distance of about seventeen miles.—*Am. Manufacturer.*

BOOK NOTICES.

KOHLRAUSCH'S PHYSICAL MEASUREMENTS: AN INTRODUCTION TO PHYSICAL MEASUREMENTS, WITH APPENDICES ON ABSOLUTE ELECTRICAL MEASUREMENT, ETC. BY DR. F. KOHLRAUSCH. Translated from the Second German Edition by T. H. Waller and H. R. Procter. London: J. and A. Churchill. 1873. For sale by D. Van Nostrand.

Their work is intended to serve as a text-book for students in experimental physics, and consists mainly of a collection of the formulæ used in correcting and applying the results of the simpler experiments in weighing and measuring, heat, light, electricity, and magnetism, accompanied in each case by such an account of the method of observation employed as may suffice to render them intelligible.

The limits which the author assigned to himself are very clearly laid down in the translators' preface, in which we are informed that "descriptions of apparatus are but rarely given, as students mostly have instruments provided for them," and also that "the mathematical knowledge required is but very elementary, as the proofs of the formulæ are only given when they present no complex arguments;" but it should perhaps have been added that, even in cases where the apparatus is simple, outlines of the mode of performing an experiment are generally alone supplied, the teacher being left to explain to his pupils the niceties of arrangement and manipulation.

It is as a collection of formulæ that "Physical Measurements" is likely to prove most useful, and from this point of view the "Introduction" seems to us one of the best parts of the book. It contains the rules for finding the mean and probable errors of a set of observations, and for determining empirical constants by the method of least squares, together with hints as to how to shorten the labor often wasted in the calculation of corrections; points on which a short practical treatise like that here provided will afford great assistance to those who are not mathematicians.

The sections devoted to weighing and measuring are full and good, especially those which relate to the use of the balance, but heat and light are not treated of in an equally satisfactory manner.

The experiments on these subjects which are described are not numerous enough to satisfy the requirements of large laboratories. Moreover, sufficient attention seems scarcely to have been paid to the fact that students should be encouraged to apply corrections to the results of experiments which they perform, not so much on account of the more accurate numerical values thereby obtained, as for the sake of the excellent practice the necessary observations often afford, and the insight gained into the theoretical principles on which they are founded.

Nearly one-half of the book is given up to Electricity and Magnetism, subjects in the study of which assistance can be more readily rendered by the method of treatment here adopted than in

those we have been discussing, as numerous mathematical formulæ are required which are in many cases obtained by calculations beyond the grasp of the less advanced pupils; and the Translators have considerably improved what was already good by several Appendices, among which one of the most important is that on Thomson's electrometer. Some preliminary sections are devoted to the reduction of observations made with the mirror and scale to angular measure, to the determination of the position of equilibrium and time of oscillation of a magnetic needle, and similar topics, while the methods of reading the various magnetometers and galvanometers, and the measurement of resistance and electromotive force, are afterwards discussed.

On the whole, the principal fault we have to find with the book is a want of fulness, especially in the earlier portions. It aims at supplying a want already felt, and which will become still more pressing as the number of those who make some progress in the study of Natural Science increases, and we are not aware of the existence of any manual which gives the information contained in it in an equally compact and handy form; while the tables, thirty in number, which fill the concluding pages, will often save time and trouble to those engaged in laboratory work. Although, then, as we have already pointed out, we consider it capable of very considerable improvement, yet probably most teachers of Experimental Physics will obtain some useful hints from its perusal, even if they do not adopt it as a text-book for their pupils.—*Abstract from Nature.*

NOTES ON A METALLURGICAL JOURNEY IN EUROPE. By JOHN A. CHURCH, M. E. With 22 illustrations. New York, 1873. 8vo., pp. 102. D. Van Nostrand.

So much exact and valuable information on technical art is rarely crowded into the same space as is to be found in the one hundred closely printed pages of Mr. Church's "Notes" of his metallurgical journey in Europe. The topics discussed are concisely handled in the analytic method, and with a fulness of detail which makes the work of permanent value. The copper process at Agordo; the mercury works at Valalta; the lead works at Mechernich; the gold and silver works at Lend,—occupy 53 pages, rich in information and details drawn from the most authentic sources. Since 1870 the processes at Freiberg have been so much changed that Mr. Church's chapter of 28 pages devoted to them will be read with great interest. The lead and silver works of the Hartz Mountains, Clausthal, Lautenthal, and the copper process at Altenau, complete this useful and unpretending memoir, which appeared first in a series of articles in the "Engineering and Mining Journal" of New York during the past year.—*American Journal of Science and Arts.*

THE CONSERVATION OF ENERGY, BEING AN ELEMENTARY TREATISE ON ENERGY AND ITS LAWS. By BALFOUR STEWART, LL. D., F. R.S. London: Henry S. King & Co. 1873. For sale by D. Van Nostrand.

In this work, one of the international scientific series, the author has in a singularly lucid manner contrived to popularize some of the most intricate problems in the philosophy of the physical sciences. Viewing the universe, as a whole, in the light of a vast physical machine, he introduces the neophyte to a view of its mode of working, so far as that is known. In the first chapter, atoms, the ultimate constituents of matter, and energy, their mode of action, are defined. The following exposition of the nature of the molecule and atom taken from somewhat farther on in the book is a good example of the author's perspicuous style; and as it regards a matter now frequently referred to in current literature, and though not very difficult of apprehension, still one rather hazily apprehended by the popular mind, it may be worth while to quote it. "Let us suppose," he says, "the continual subdivision of a grain of sand" until we arrive at "the smallest entity retaining all the properties of sand"—this is the molecule; and if we continue the subdivision further, "the molecule of sand separates itself into its chemical constituents, consisting of silica on the one side and oxygen on the other. Thus we arrive at last at the smallest body which can call itself silicon, and the smallest which can call itself oxygen," and "these constituents of the silica molecules are called atoms, so that we say the sand molecule is divisible into atoms of silica and oxygen." In the succeeding chapters the change of mechanical energy into heat is considered, and some of the most remarkable and important discoveries of the century in connection with this subject are explained, and the forces and energies of nature—gravitation, electricity, and the rest, defined, their transmutation of energy illustrating what is known as the correlation of the physical forces, and lastly, the dissipation of energy, the closing chapter being on "the position of life." One very interesting point is the reference to the ideas in physics of several of the leaders of thought in ancient times—to Heraclitus of Ephesus, Democritus, the originator of the doctrine of atoms, and Aristotle, regarding whom the author observes that they possessed great genius and intellectual power, but were deficient in physical conceptions, and that, in consequence, their ideas were not prolific. In the chapter on the dissipation of energy, he felicitously describes coal as the store which nature has laid up as a species of capital for us, while wood is our precarious yearly income, so that "we are thus at present very much in the position of a young heir, who has only recently come into his estate, and who, not content with the income, is rapidly squandering his realized property."—*Iron.*

SIMPLE PRACTICAL METHODS OF CALCULATING STRAINS ON GIRDERS, ARCHES, AND TRUSSES. By E. W. YOUNG. London: Macmillan & Co. For sale by D. Van Nostrand.

This work fulfils the promise implied in the title, and, inasmuch as students as well as engineers differ in their tastes regarding the methods of dealing with practical problems, this work will undoubtedly become a favorite of a greater or less number.

It will, however, prove unsatisfactory to the majority of American engineers, by reason of the omission of the leading forms of trusses employed in this country. The methods of calculation are simple enough, but not more so than we find in the later works on this side of the Atlantic, while

these latter present the advantage of discussing forms of bridges that are preferred here, but are rarely seen in Europe.

The type and plates of the book are unexceptionable.

ANIMAL LOCOMOTION; OR WALKING, SWIMMING, AND FLYING, WITH A DISSERTATION ON AERONAUTICS. By J. BELL PETTIGREW, M.D. London: Henry S. King & Co. For sale by D. Van Nostrand.

In this volume of Messrs. King's excellent International Science series we have an original work by a well-qualified scientist, on what may be termed the animal machine in motion. There is certainly no part of the animal mechanism in which there are finer evidences of adaptation than those employed in locomotion through either element; and when the subject comes to be examined in minute detail, and under the light of careful observation and exact science, many curious relations are perceived, and many indications present themselves of high practical importance. Thus it is made evident that walking, swimming, and flying are only modifications of each other, and that weight, instead of being an impediment to flight, is absolutely necessary to it, two facts of much encouragement to experimenters in aeronautics; farther, that although the wheel of the locomotive and the screw of a steamer differ from the limb of a quadruped and the fin of a fish, still the curves which go to form the wheel and screw are found in the travelling surfaces of all animals, whatever their mode or means of progression. From which, and other similar revelations with which Dr. Pettigrew's book teems, inventors may learn to go to nature for many a hint and help in other things besides artificial locomotion, if they only go the right way; although much has already been thus gained, even through merely superficial and empirical knowledge, as in the well-known instance of the construction of Eddystone lighthouse. And recent and more cafeful experiments have elicited the interesting fact that the undulation or wave made by the wing of an insect hovering or flying corresponds, in a marked manner, with the track described by stationary and progressive waves in fluids, and with the waves of sound—the wing acting on those very curves into which the atmosphere is naturally thrown in the transmission of sound. It would be impossible to follow the author through all the elaborate and minute details to which he introduces his readers, commencing with a description of the instruments of progression, and following with a full account of the laws and methods of working of the multiform organs, by which the immensely varied living forms move on land, on and in the water, and through the air. In the closing passages of this division, he observes that their "indomitable courage and miraculous powers invest" birds "with a superior dignity, and secure for their order almost a *duality of existence*," a remark the latter part of which recalls Sir Boyle Roche's famous axiom, that a man couldn't be in two places at once unless he was a bird. On the subject of aeronautics, Dr. Pettigrew, while stating his case temperately enough, seems sanguine of the ultimate success of the now systematic attempts to give to man the power of artificial flight. Reasoning from analogy and nature, he holds that the "tramway of the air may and will be traversed by man's ingenuity at some period or other." Weight is no obstacle, but rather favorable than otherwise, for progression through the air; and the materials and forces employed in flight are literally the same as those employed in walking and swimming; whilst now that, by steam, man has outraced the quadruped on land and the fish in the sea—each having been, "so to speak, beaten in its own domain"—the necessary physical power has been acquired. In this chapter the chief inventions for aerial locomotion are described and compared, and a "wave wing" and "aerial screw" designed by the author on scientific principles is advocated. In conclusion, he maintains that, however difficult his task, the aeronaut, in attempting to produce a flying machine, is not attempting an impossible thing. The movements of the tail of the fish and of the wing of the insect, bat, and bird, can, as he shows, be readily imitated and reproduced, while in the analogical instances of the locomotive and steamboat, success was attained, not by servile imitation of living things, but by the production of motors adapted to land and water in accordance with natural laws, and in the presence of living models. And if the difficulties are greater in this than in the other cases, the reward will be correspondingly great. "Of the many mechanical problems before the world at present, perhaps there is none greater than that of aerial navigation. Past failures are not to be regarded as the harbingers of future defeats, for it is only within the last few years that the subject of artificial flight has been taken up in a true scientific spirit. Within a comparatively brief period an enormous mass of valuable data has been collected. As societies for the advancement of aeronautics have been established in Britain, America, France, and other countries, there is reason to believe that our knowledge of this difficult department of science will go on increasing until the knotty problem is finally solved. If the day should ever come, it will not be too much to affirm that it will inaugurate a new era in the history of mankind; and that great as the destiny of our race has been hitherto, it will be quite outlustred by the grandeur and magnitude of coming events." We must add that the volume is admirably illustrated, chiefly from original drawings by the author, which makes still more intelligible his very popular and lucid expositions.—*Iron.*

A TREATISE ON STEAM BOILERS: THEIR STRENGTH, CONSTRUCTION, AND ECONOMICAL WORKING. By ROBERT WILSON. London: Lockwood & Co. 1873. For sale by D Van Nostrand.

Mr. Wilson gives us, in a well-digested and arranged series of chapters, all the salient points of theory and practice, past and present, derived from various sources. Thus, after a preliminary *resumé* of the chief types of boilers which have been used, whence we infer that Mr. Wilson believes in the tubulous variety of the typical boiler of the future, without, however, being greatly enamored of any of its existing representatives, his readers are taken through a brief exposition of the various kinds of surfaces, cylindrical, spherical, cambered and flat, under which boiler-shells are classified; and they are then introduced

to the materials, cast iron, wrought iron, and steel, of which boilers have been or are now made, with their special properties and characteristics; and then to the subjects of riveting, welding, and the special modes or designs of construction adopted. The mountings and fittings of boilers and furnaces are then successfully treated of, feed apparatus, safety-valves, steam and water gauges, blow-out appliances, steam domes, furnace doors and frames, fire bars, bridges, ashpits, etc.; especial stress being justly laid upon the necessity, means, and difficulties of making the connections thoroughly sound and tight. Incrustation, wear and tear, the safety-factor, testing, and explosions, each successively claim and receive attention; and the concluding chapters are devoted to the combustion of coal and coke, firing and the prevention of smoke; heating-surface; boiler-power, and the properties of saturated steam; the whole being suitably illustrated by diagrams, formulæ, and useful tables of various kinds.—*Iron.*

MISCELLANEOUS.

At a recent meeting of the Paris Academy, M. Cazin called attention to certain cases of intermittence in the voltaic current not previously observed. One of his experiments is as follows:—A voltaic circuit is formed with 20 Bunsen elements and a coil inclosing an iron tube. It may be opened or closed at will by means of a platinum point and a drop of mercury, which communicate respectively with the two rheophores. When the platinum does not touch the mercury, and the two are put in communication with the armatures of a condenser (formed with plate of glass, etc.), one hears a continuous sound in the iron core. The same effect is produced when, the condenser being suppressed, a layer of alcohol is interposed between the mercury and the platinum point. The sound ceases when the alcohol is removed, the platinum and mercury being separated by a layer of air; also when the point is immersed in the mercury. These facts (M. Cazin thinks) show that the current passes through the glass in the first case, and through the alcohol in the second, and that its passage is intermittent. The iron core undergoes a rapid succession of alternate magnetizations and demagnetizations. Each of the demagnetizations causes a slight sound in the core; the rapid succession of these producing the continuous sound heard. He considers the cause of the intermittence to be the condensing action of glass and alcohol. When the two faces of the insulating body, which are in contact with the rheophores, have acquired a certain potential, a discharge takes place through the insulating layer; the magnetism of the core increases during the charge of the condenser, and diminishes during its discharge. The sound is produced during the diminution of the magnetism.

Professor Hayes gives, in the "American Chemist," the following opinion regarding the formation of deposits in boiler flues: They are of two kinds, both of which are capable of corroding the iron rapidly, especially when the boilers are heated and in operation. The most common one consists of soot (nearly pure carbon) saturated with pyroligneous acid, and containing a large proportion of iron if the deposit is an old one, or very little iron if it has been recently formed. The other has a basis of soot and fine coal ashes (silicate of alumina), filled with sulphur acids, and containing more or less iron, the quality depending on the age of the deposit. The pyroligneous deposits are always occasioned by want of judgment in kindling and managing the fires. The boilers being cold, the fires are generally started with wood, pyroligneous acid then distils over into the tubes, and, collecting with the soot already there from the first kindling fires, forms the nucleus for the deposits, which soon become permanent and more dangerous every time wood is used in the fireplace afterward. The sulphur acid deposits derive their acids from the coals used, but the basis material, holding these acids, is at first occasioned by cleaning or shaking the grates soon after adding fresh charges of coal. Fine ashes are thus driven into the flues at the opportune moment for them to become absorbents for the sulphur compounds distilling from the coals, and the corrosion of the iron follows rapidly after the formation of these deposits.

A Novel and Simple Electric Light.—Dr. Geissler, of Bonn, Germany, whose name is inseparably associated with some of the most beautiful experiments that can be performed by the agency of electricity, makes an electrical vacuum tube that may be lighted without either induction coil or frictional machine. It consists of a tube an inch or so in diameter, filled with air as dry as can be obtained, and hermetically sealed after the introduction of a smaller exhausted tube. If this outward tube be rubbed with a piece of flannel, or any of the furs generally used in exciting the electrophorus, the inner tube will be illumined with flashes of mellow light. The light is faint at first, but gradually becomes brighter and softer. It is momentary in duration; but if the tube be rapidly frictioned, an optical delusion will render it continuous. If the operator have at his disposal a piece of vulcanite, previously excited, he may, after educing signs of electrical excitement within the tube, entirely dispense with the use of his flannel or fur. This will be found to minister very much to his personal ease and comfort. He may continue the experiments, and with enhanced effect, by moving the sheet of vulcanite rapidly up and down at a slight distance from the tube. This beautiful phenomenon is an effect of induction.

Economical Consumption of Fuel.—An exhibition of appliances adapted to the above purpose is about to be held in Manchester, by the Society for the Promotion of Scientific Industry. The exhibition will comprise: (1) Appliances which may be adapted to existing furnaces, etc., whereby an actual saving is effected in the consumption of fuel; (2) appliances which may be adapted to existing furnaces, etc., whereby waste heat is utilized; (3) new steam generators and furnaces, boilers, and engines specially adapted for the saving of fuel, and appliances whereby waste products are utilized, and the radiation of heat prevented, etc., etc. A variety of similar apparatus for manufacturing, agricultural, and domestic purposes, will also be exhibited. The exhibition promises to be interesting and instructive.